PERCEPTIONS OF ONE'S SELF AND OTHERS IN VIRTUAL REALITY

Designing minimal form virtual embodiments that establish social presence, reduce bias and raise involvement in VR environments.

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May 10, 2017

Submitted in partial fulfillment for the degree of Master's of Graphic Design

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With immense gratitude, I would like to thank everyone who has helped me throughout the course of this endeavor. I wish to express my deepest thanks to my committee: Helen Armstrong, Derek Ham, and Denise Gonzales Crisp for guiding me along this journey. I would also like to thank my parents, Lou and Patricia Zapata and my family for cheering me along. Also, to my fellow classmates for always showing me new perspectives.

This project is dedicated to my parents.

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ABSTRACT

When users enter a digital environment, like making an account on a computer or playing a game, the application gives them the opportunity to create and customize what they will be represented as in that context (i.e. their embodiment). In games, users can spend hours customizing their characters. This is not unlike an individual spending time picking out an outfit for the day. Giving users this opportunity for customization increases the likelihood of bias and stereotypes. In the attempt to make things more immersive, content creators tend towards the most realistic approach possible. However, photorealistic embodiment inhibits expression of personal information as users begin to connect with one another. My investigation explores ways for users to enter a virtual reality environment, embody a form that reduces bias and stereotypes, while attempting to raise participation others in the space. I built upon the research Bailenson and Blascovich have been doing in the Virtual Human Interactions lab while utilizing Biocca and Harms Networked Minds Theory for measuring Social Presence. In my investigation, I used research through design, case studies, interviews and experiments to establish a prototype. My hi-fidelity prototype creates a testing ground for further exploration in minimal form representation in VR. The tool allows designers and psychologists to observe passively or interact with participants in the space while collecting data for future analysis.

PRIMARY RESEARCH QUESTIONS

HOW CAN MINIMAL INDIVIDUAL VISUAL REPRESENTATION COMMUNICATE SOCIAL PRESENCE IN A VIRTUAL REALITY ENVIRONMENT?

SUBQUESTIONS

How does the visual representation of behavior affect individuals inside a task-oriented space?

How does variation in a form's size, color and texture affect an individual's ability to distinguish animate objects from inanimate objects?

How can the visual representation of an individual influence how they interact with others in virtual reality?

BASIS FOR INVESTIGATION

Virtual reality moved from the theoretical and experimental domain towards home use when Oculus announced their head-mounted display (HMD) in 2014. Since then more companies have released HMDs and they are slowly getting into the hands of designers and creators. Like most forms of technology, it starts with programmers and developers and then trickles into the hands of the consumer as it becomes more and more useful for the consumer's daily lives. Whenever designers get their hands on new technology, they need to ask themselves, "What is good practice?" This happened with operating systems in personal computers, websites, interfaces and apps on mobile devices, and these were all in the past 30 years. It is about learning what can translate from our past medium and what needs to be redefined. This is where I find room for investigation. On devices like the computer, a user's location on the screen is by default represented by an arrow-like cursor. On a mobile device, there is no direct representation of the user, they simply interface with it like they would with a book, a microwave, or a car. So, why in VR do developers jump back to realistic representations to interface with a 360° space. What representations, either physical or behavioral, need to be represented in the virtual space for me to feel present?

My first instance with a VR headset was the Oculus Rift Developers Kit 2 and although it was buggy, I saw potential.My second instance was with the HTC Vive, which was a much more finished product, and it got me excited. I was painting in Google's Tilt Brush; I was playing in Steam's The Lab; I was sitting on the bow of a sunken ship. It was very exciting, but I was all alone.

While feeling alone is a common problem in Virtual Reality, researchers have explored this in other computer-mediated mediums. This phenomena of feeling as if one is with another individual through a digital medium is called social presence.

During my investigation, I narrowed my studies to specific visual attributes that could be used to establish social presence. Future explorations can expand upon these designated attributes to investigate textual, auditory, and haptic features. I find this to be the starting point for further discussion and investigation. In the 1972 game, Pong, users could understand the presence of other players from a single bar moving up and down the screen. With VR, what is the starting point that helps users comprehend the presence of others?

CONDITIONS & CONTEXT

FEELING TOGETHER

Books, movies, and television shows reflect upon the moment in which we jack our brains into the internet and disappear from this world. The Matrix suggests we live in a fake world, but we are not aware of this fake reality unless someone else has taught us, or woken us up. The novel, Ready Player One, portrays VR as an escape from the depression and abysmal qualities of the future. The main character, Wade Watts, spends so little time outside of the Oasis, the VR world, that he forgets what season it is. While these possibilities feel bleak, some of the fundamental attributes of how people interact with one another in VR, even in these dystopian worlds, can be real. In these fictional stories, communities arise in the virtual worlds. People have friends, enemies, strangers, acquaintances. There is power in entering these alternative realities with other people.

People strive to connect with each other. When the precursor to the internet, Arpanet, was first introduced, scientists used it to share research and collaborate with each other. Soon after it became a place scientists used to gossip, flirt, and talk about each other's lives. It became a place for people to become more familiar with each other. Even after the internet went mainstream and massive multiplayer online role playing games, MMORPG, became popular, players still used them as a platform to chat (Turkle, 157 - 158).

In the years before the internet, digital communities, even temporary ones sprung up and people flocked to them. Kipling Williams, a social psychologist from Purdue University, did an ostracism study in 2006. His study was inspired by a moment when he was in the park and a Frisbee rolled up next to him. He threw it back at the men who lost it, and then they threw it back to him. He recounts this moment of community and togetherness from the bond they shared while tossing the Frisbee a couple of times between each other. Then, as quickly as it started, the men went back to playing by themselves. He was left out of the game. He stated that he "felt terrible and awkward and helpless."

In his study, Williams used a computer and participants playing with a virtual ball while hooked up to an MRI machine. He found that people reacted the same way as he did during his real-life experience (Blascovisch and Bailenson, "Infinite" 67 - 68). If feeling left out creates negative feelings of pain and helplessness, then being together creates positive feelings of joy and satisfaction. It is the power of our need to share moments and experiences with one another that forms the fundamental platform for my investigation.

Once together in the space, what needs representation for both of us to feel each other's presence? Can a head-tracked gesture of a box suffice or does a user need to see eyes, a nose, a mouth, and hair to feel that the other representation is a person that they can interact with? Developers, after testing simple objects like spheres, have moved towards realistic representation, but is there another way to optimize social presence between users in a virtual reality environment? Can designers establish social presence without relying on representations that mimic a human body?

LESS REALISM, MORE COMFORTABLE

There is little meaning in highly realistic representation itself. In art, realistic paintings come from the juxtaposition of the objects instilled by the artist, not the objects themselves (McCloud, 55). Gamers can see this shift from the two-bit pong games with bar representations towards the now photorealistic avatars. As VR becomes more prominent this desire will be sure to follow. This is due to the thought that the best way to be immersed in an VR environment is to trick the senses into thinking the participant has left the physical world and been transported somewhere else. Is this truly quintessential though? Does realism truly facilitate our behavior in a VR environment? Does realism help our relationships with other people?

A study led by the Virtual Human Interactions Lab at Stanford University with psychologist Jeremy Bailenson, found that if less realistic digital embodiments represent two individuals, they feel more comfortable divulging personal information about themselves. The three conditions explored in the study were voice only, a geometric representation they called emotibox, and a video conference protocol. As part of the study, Bailenson et al. tested how a virtual embodiment with different levels of behavioral realism affected communication between two individuals (Bailenson et al, "Behavioral Realism").

In the study, the emotibox was a colored box that tracked the user's face around the screen in three-dimensional space. Various tracked facial features controlled the color qualities of the box. The wider the user's eyes, the brighter the box became. The distance from the corners of the user's mouth controlled the blue-yellow spectrum. The more someone smiled, the more yellow the box turned. The more someone frowned, the bluer it became. The distance from the user's eyebrows to their pupils controlled the red-cyan spectrum. Wider distance resulted in more cyan. The user's height and width of their month controlled the height and width of the box. Due to all the metrics represented from a given user, the emotibox had high-behavioral realism but low form realism. In both verbal self-disclosure and non-verbal disclosure, the emotibox produced more disclosure over the video conference. The video was comparable to verbal self-disclosure but greater than nonverbal disclosure (Bailenson et. al, 359-368).

According to this study, less realism reduces the barrier for users to disclose information to each other; however, it also lowers co-presence and emotional detection. This study, however, was conducted on a computer screen, rather than a 360° VR environment. A user could expect that trying to read a box that changes color and shape unknown to them would be harder to read than facial expressions the user has learned his/her whole life. Could an alternative abstract representational system allow users to express emotions in a natural manner, building on current cultural norms, but avoiding realistic bodily representations? In the emotibox study, the less realistic representation results in a depiction that has more meaning rather than something that is just realistic.

BALANCED PARTICIPATION

Whenever people are working together to make decisions, getting everyone to talk and add value to the conversation can be difficult. This is enough of a problem that designers have explored possible ways of mitigating unbalanced conversations. Consider the Conversation Table developed by David Rose at the MIT media lab. The table lit up based on which person at the table was talking more. Rose's students worked on similar problems using hydraulics to push a ball around the table as if "passing the talking stick." How might digital media help facilitate conversation in a VR space?

A 1986 study out of Carnegie-Mellon University explored how computer-mediated conversation changed making career choice problems in a group. In this experiment, the participants in a computer-mediated conversation conversed longer than in a face-to-face conversation. In addition, they behaved more as social equals and expressed uninhibited behavior. The decisions ultimately made were based off the group's decisions rather than an individual's opinion (Siegel et al, 157).

The Bailenson et al. study with the emotibox mirrors the results from this study; people felt more comfortable expressing their opinions when the representation reduced the verbal and nonverbal social cues that can affect a face-to-face conversation. Siegal et al concluded that participants were more task-oriented in the conversation when computers mediated the conversation, as well.

Imagine a situation in which the representation of individuals in an environment is less and less realistic. Does the fact that they can express themselves without inhibitions affect how they embody the virtual representation? Do they find it easier to recognize each other if they are represented similarly and does this help them create connections that encourage them to work together? Can this help them learn there is a task in their environment and get it done? These are the questions I'm asking myself in my investigation. How can a balanced participation affect individuals solving a seemingly unknown problem?

LESS BIAS

Bias and stereotypes are cultural phenomenon that penetrate our psyche and influence how we interact and behave with one another. The Proteus Effect explains how users conform to expectations generated by identity expressed through avatars and digital embodiments (Blascovich and Bailenson, "Infinite" 102). In cases explored by Bailenson, the physical characteristics of an individual's digital representation affected how the individual performed on task both inside the digital world and outside of it. The resulting behavior shift is known as Stereotype Threat: an individual feels they must conform to that social group's stereotype. Race influences people's behavior towards others without them even realizing it. While it is difficult to change one's race in grounded reality, in virtual reality it is easier. Thus, we can explore and study the influence of bias and stereotypes by manipulating representation within a VR space.

Immersive virtual reality environments are an effective way to investigate what social characteristics influence individuals. The Virtual Human Interactions Lab explored how embodying a race affects an individual's behavior and perceptions to that group of people. In an environment where white and nonwhite participants were switched between Black or White –racial classified embodiments—participants that were embodied Black representations elicited greater racial bias while White representations elicited more favorable behavior (Grooms et al., 14).

Gender bias can even affect how a user completes various tasks. Ratan and Sah, in an all-female study, explored the stereotype that men are better at math than women. They found that women who had a male embodiment performed better in a math test than the women who had a female embodiment (372). The math test portion of the study was tested after the participants played a video game.

In grounded reality, we cannot change our race or gender easily for the sake of a test. In a virtual reality environment, cultural cues can be stripped to reduce bias and stereotypes. Looking at avatar creation in video games gives some insight into possible features that need to be stripped away. Users change certain attributes of the avatar to help distinguish one player from the next. Some of these attributes are gender, body shape, skin color, hair color and style, eye color and shape, and clothing. My investigation considers what attributes a user requires to distinguish one user from another without introducing bias and stereotypes.

ASSUMPTIONS & LIMITATIONS

ASSUMPTIONS

VR technology used in head-mounted displays will continue to improve and make the experience more comfortable. In doing so, it will reduce the adverse conditions of disorientation, nausea, and motion sickness over the next 5 to 10 years.

Primitive shapes do not communicate cultural or other preconceived notions of self as clearly as realistic avatars.

The demand for VR will continue to develop. Increasingly we will experience social activities within this space as an alternative to the physical world; therefore, this research will be more and more relevant to social interactions.

LIMITATIONS

Social Presence Theory has a variety of definitions from Short, et al, Lombard and Ditton, Rettie, Slater and Usoh, Witmer and Singer, Tu, and Swan. In these they focused more on the ability to feel co-present with another, while Biocca and Harms' definition of social presence is about creating a relationship among the users in which they perceive their emotions as opposed to just their presence. My studies use the Biocca and Harms definition. Future work could expand on this definition.

Cultural limitations – The visual language used in my investigation is bounded by my own cultural norms and understandings. The research I've used tends to draw from Western sources. Because of this, my design decisions will not necessarily reflect those of different cultures.

The user tests were limited to areas near the classes in session to make it more time efficient and not to disrupt the class I was borrowing the students from.

I limited the headset prototypes to mobile devices and Google Cardboards because of the need for constituency for all participants in the user tests, and due to the need to power larger headsets with separate computers.

Explorations used small non-diverse samples of the population.

Time limited the scope of this project. More time and resources would have allowed me to add more layers than just visual attributes.

Analysis ability –I am not a psychologist nor a statistician, a more speculative approach limits my analysis of my tests.

DEFINITIONS OF TERMS

Virtual Reality

a digitally-made immersive environment where social interactions occur that can but do not have to mirror grounded reality.

Grounded Reality

Commonly known as physical reality or real world. The reality into which one's consciousness is born.

Immersive

a state where one feels present in an experience to a point that they feel they can engage mentally or physically.

Digital Embodiment

the way an individual is represented within the virtual reality environment.

Head-mounted display

A device with a digital screen on one end and 2 optical lenses that allows a user to get the feeling that they are considering a different reality.

Social Presence

The idea that someone feels another person's virtual presence through interaction with them, either by communicating or seeing results from their movements.

Intimacy

The degree to which an individual exhibits behavior as a function of proximity, eye-contact and smiling, as well as, details personal topics of conversation to another.

Immediacy
The degree to which two individuals interact as measured in directness and intensity.

Involvement
The degree to which an individual participants in a conversation with another.

Co-Presence
The degree to which an individual and another appear to share an environment together, that is the degree of mutual salience and sensorimotor accessibility of the individual and perceived other.

Psychological Engagement
The degree to which an individual perceives the other's mental state as accessible in terms of their emotional responses.

Behavioral Interdependence
The degree to which an individual perceives the other's mental state as accessible in terms of their behavioral responses.

Subjective Psycho-behavioral symmetry
The degree of symmetry or correlation between user's sense of social presence and their perception of their partner's sense of social presence.

Intersubjective Psycho-behavioral symmetry
The degree of symmetry or correlation between the user's sense of social presence and their partner's perception of user's social presence.

AREA OF INVESTIGATION

A few theories and frameworks help me in my investigation to establish and understand the current situation and measure the effectiveness of my prototypes. Regarding the study of VR and what helps people interact in VR, I dip into psychological theories to understand what is really going on. The Social Presence Theory helps me to determine appropriate qualities to measure. The Human Embodiment bridges that gap between psychology and design. Human Embodiment lists out various forms of digital and physical embodiments and ranks their form as realism versus behavioral realism. Iconic Representation considers how visual form and language can be used to establish meaning. In Semiology of Graphics, the Retinal Variable breaks apart attributes of object representation used primarily in maps and data visualization to make values distinguishable. I use these four frameworks either to understand and classify the visual precedents that I base my studies on, or to evaluate my studies to determine their effectiveness.

SOCIAL PRESENCE

Social Presence Theory is when a user feels that he/she is in a digital environment with someone else. Short, Williams and Christie developed the theory to explain the effect telecommunications media has on communication. In the original definition, social presence is the degree of salience between two communicators communicating through a given medium. Their definition was posed to describe how degree of salience has greater or lesser effects on social presence, such that video is high in salience and would result in high social presence while audio is low in salience and would result in low social presence (Lowenthal, 5). The theory evolved when online platforms were popularized.

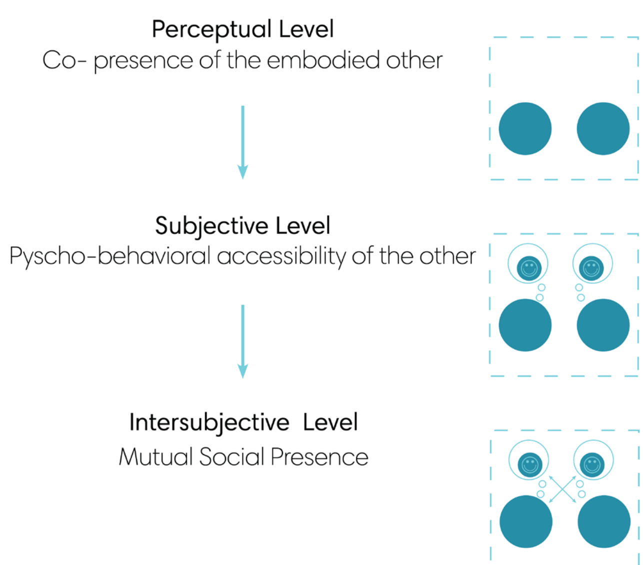


Fig 1: Diagram of the different levels of social presence

Users could project themselves through online discussions using text only. Other users could perceive their presence through behavioral gestures such as emoticons, telling stories and using humor (Lowenthal 6). Since then an array of social networks surfaced exploring social presence such as: collaborative work environments, mobile and wireless telecommunications, high-bandwidth teleconferencing, agent based e-commerce, speech interfaces and 3D social virtual environments (Biocca and Harms, 3).

Frank Biocca and Chad Harms, from the Media Interface & Network Design Lab out of Michigan State University, frame social presence in a way that considers whether two communicators feel present with each other but also whether they feel connected with each other. Much like the studies done with online forums where communicators established higher levels of social presence when they used things like emoticons and humor, the definition should also include how accessible each other's behavioral and psychological actions are. Biocca and Harms define Social Presence as

> *Social presence is the moment-to-moment awareness of co-presence of a mediated body and the sense of accessibility of the other's psychological, emotional, and intentional states (12).*

In this definition, social presence is a sliding scale that can vary depending upon the technological representation of the other being over the course of mediated interactions. The definition breaks into three levels: Perceptual Level, Subjective Level, and Intersubjective Level.

Perceptual Level

Co-Presence of the embodied other.

> *This definition deals primarily with the detection and awareness of the co-presence of other's mediated body (Biocca and Harms, 13).*

This is the threshold point where a static object in a space goes from being considered "dead" to something that is "alive." It is the point that the representation is perceived as somebody sentient. This is broken up into two moments: when individuals sense that they can perceive others, and when others can perceive them (Biocca and Harms, 13). One way that representations can facilitate social presence is through vertical bilateral symmetry and horizontal symmetry. When an object is upright it gives off certain social cues, like physical health. Even when motion is added to abstract shapes, it elicits automatic responses of presence (Biocca and Harms, 17). Through these movements and biological detection, an individual establishes attentional awareness of the other. As these higher levels of co-presence are established, the interaction shifts into level 2: The Subjective Level. In this level the other individual's behavior, emotional, and intentional states are accessed.

Subjective Level

Psychobehavioral Accessibility of the other.

> *These dimensions of social presence focus on the perceived accessibility of the other, the sense that the user has awareness of and access to the others, attentional engagement, emotional state, comprehension, and behavioral interaction(Biocca and Harms, 13).*

In this level, users simulate the other individuals' minds in their own. They use the perceived accessible states to understand the environment in front of them. This is measured in four dimensions: attentional engagement, perceived emotional interdependence, perceived comprehension, perceived behavioral interdependence. Attentional engagement, like in the first level, deals with the degree the other's bodily cues draws the attention of the user. Some level of the behavior is required to be represented in the environment to allow for this accessibility. Perceived emotional interdependence is the ability of a user to notice the other's emotional state and empathize with them through the medium. As emotions are transferred between the user and other individuals, the effect of interdependence is greater.

Perceived comprehension is the degree to which the users feel that they understand the other's intentions, motives, and thoughts. This, like emotional interdependence and behavioral interdependence, is the illusion that the user can read these states off the other individuals. Perceived behavioral interdependence, much like the emotional interdependence, links the behaviors of the user and other individuals. For example, if one waves, the others wave back. This can also be defined as the degree to which the user's actions are reactions or interactions with the other's behavior.

Intersubjective Level

Mutual Social Presence.

> *The interaction between the user and one or more mediated others is dynamic. The user's sense of social presence is in part a function of how they perceive the other's sense of social presence of them. At this level Networked Minds social presence theory and measure access the degree to which one individual perceives the social presence to be mutual (within-interactant symmetry), and intersubjectively the degree to which the pair of interactants share this sense of social presence among each other (cross-interactant symmetry) (Biocca and Harms, 13).*

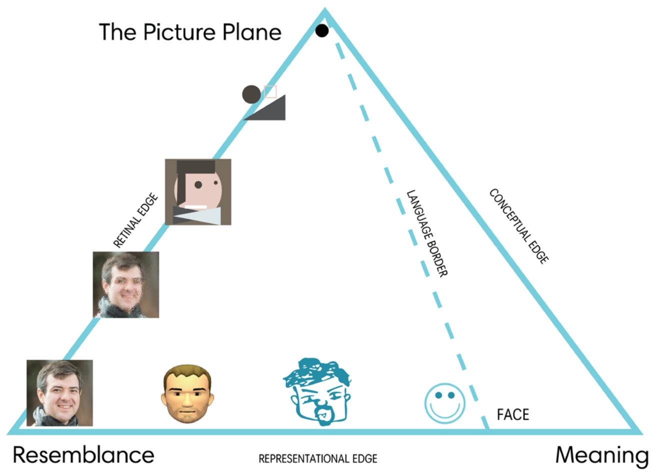
In this level, Biocca and Harms, suggest that to reach the highest level of social presence both the user and the other individuals need to reach the state where they perceive the other as socially present as well as the other perceives them as socially present. It is in this symmetry of perception that the communicators reach a mutual state. It is measured in the within-interactant symmetry and cross-interact symmetry. The within-interactant symmetry is the degree of symmetry to which the user's sense of social presence and their perception of the other's sense of social presence. This facilitates the level of successive interaction. For example, if the user feels they are not being fully understood in their intentions they might clarify to help make things clearer. In a text-based environment this can done with a winking face, or "hehe" to show less serious intentions in an otherwise hurtful comment. In VR environments, maybe the user does a slight nudge or another gestural indicator. Cross-interactant symmetry is the degree of symmetry between the user's sense of social presence and the other's perception of the user's social presence. Cross-interactant symmetry is the final level of reciprocity in Biocca and Harms social presence definition. In this level, social exchange is about both individuals reaching a point that they perceive themselves and the other mutually on in both co-presence and psycho-behavioral accessibility. It is through this definitions and frameworks I can understand and measure user's social presence within my investigation.

People are inherently social people. The interactions that people have with each other provides evidence of their own existence. In an area where someone's existence could be questioned, social interaction or even acknowledgement of another's presence adds affirmation to that user. Given the new paradigm that is present in virtual reality, using social presence gives researchers, developers, creators and the like the ability to evaluate the effectiveness of social interactions to help the users establish their own digital existence.

VISUAL REPRESENTATION

Visual Representation is a way of categorizing the appearance of various art forms based on the way they are presented. Scott McCloud, comic book artist and theorist, created "The Big Triangle." The Big Triangle classified Iconic, Photorealistic and Abstracted Representation. The triangle asserts that when iconic representation moves away from something pictographic and towards something textual, the representation gets closer to less arbitrary, true meaning. McCloud breaks the three vertices of The Big Triangle into Resemblance, The Picture Plane and Meaning.

Fig 2: The Big Triangle



Resemblance

Resemblance is the area of the triangle where the visual imagery used matches as closely to what we see as possible. This can also be referred to as realism. In the situation where I want to represent my face, the highest level of resemblance that this paper medium allows is a picture. The picture asks the viewer to only receive this as information, as compared to perceiving there being a deeper meaning.

In terms of comic books and art, McCloud puts comic book artist like Drew Freidman and painter, Johannes Vermeer, in this corner (52). Due to the photorealistic nature of this corner, artists that favor this area tend to be drawn by "a sense of the beauty of nature (57)." People are also drawn to the immersive factor in photorealistic resemblance. High levels of resemblance allow for the artist to put greater levels of intent into the piece and allow the reader to make decisions on what they are noticing, as in Johannes Vermeer's painting Girl with the Pearl Earring.

Meaning

Meaning is the area on the far right-side of the triangle. Going from Resemblance towards meaning, the visual imagery goes through an iconic abstraction. Lines used for representation move away from pictorial and shift into something textual. In the figure, there is a dotted line between the vertices. This is the Language Border where the representation shifts. McCloud calls this side meaning because writing is perceived information (49). Reading and understanding the context printed in a language takes time and in words there lies no semblance of resemblance. McCloud puts the bottom line connecting the two vertices of Resemblance and Meaning as a spectrum between Received and Perceived. Realistic imagery is received information, while written language is perceived information. Some type takes on a form that is more about the visual and less about the idea; this sit closer to the line. In terms of comic books, sound effects text fall, like "WHAM!" or "SPLASH!" fall just over the Language Border, and the dialogue sits closer to the vertex.

The Picture Plane

The Picture Plane is the point where there is visual abstraction, as compared to iconic abstraction. In this abstraction, the visuals leave both resemblance and meaning. The imagery used is reduced to its fundamental variables such as point, line and plane. This is the type of area that prompts the viewer to ask, "What does it mean?" and "What is it?" The reply is "It 'means' what it is (50)." In terms of art this area includes De Stijl artist like Piet Mondrain and Theo Van Doesburg. McCloud includes this vertices in his categorization to define when imagery departs from the representational edge and pushes upwards.

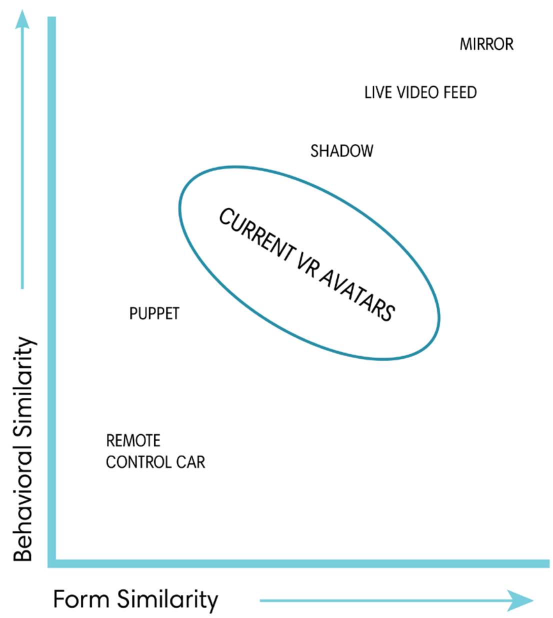
This form of categorical representation is not a full proof; it is largely dependent on comparing one item to the next. Within that categorization, it can visualize trends spurring within art forms, as well as compare one art form to the next. In my investigation, I use the Big Triangle to look at visual precedents to see where current VR digital embodiments fall. From that, I define an area of exploration that pushes the discussion of embodiments upward.

Abstracting the visual representation along the representational edge of a person allows more people to relate to this individual as if it was them (McCloud, 43). In abstracting visual representation along the retinal edge, what form could allow for generalized embodiment in a VR environment?

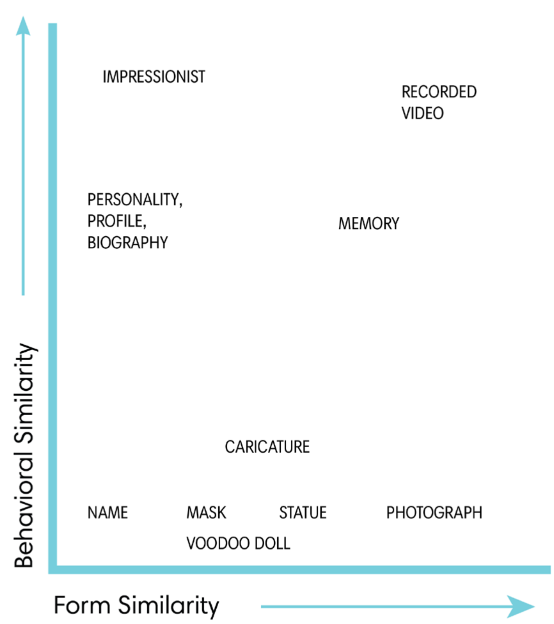
HUMAN EMBODIMENT

Jeremy Bailenson, director of the Virtual Human Interactions Lab at Stanford University, devised a framework to classify different forms of embodiments in respect to when and how they are embodied. The points are broken down into behavioral and form similarity and whether they are embodied in real time or not in real time. Bailenson points out that embodiments exist in more than just digital representations. They also exist in physical representations or conceptual representations. This is found in items like remote control cars or memories. While in his work, he uses the word avatar for digital representation, I found that based on his framework and cultural understanding of avatar, digital embodiment opens the door to broader definition of representation that encapsulates the desire for users to immerse their consciousness into it and embody it.

Fig 3: Human Embodiment divided into real-time control and non-real time control



Real Time



Non-Real Time

Form Similarity

Form Similarity is a continuum for how close an object matches the form of the person controlling it. In the framework, remote control car is low form similarity because people have little resemblance to a plastic motorized car. A recorded video has high form similarity because while the video is represented in pixels the arrangement of them resemble more closely a human. Much like McCloud's Big Triangle, this framework compares one item to the next. There is no definitive value to the placement. Rather it gives viewers a method of judging one embodiment against another to draw conclusions and build from.

Behavioral Similarity

Behavioral Similarity, like form similarity, is a continuum for how closely an object matches the behavior of the person controlling it. Using the same examples as above, a remote-control car has slightly higher values of behavioral similarity because it can move forward, turn, and backup. A drone would have lower behavioral similarity because the person controlling it cannot alter its location up and down. A recorded video has high behavioral similarity, like form similarity, because the pixel representation moves in a way that mirrors the person being filmed almost perfectly.

Real and Non-Real Time Embodiments

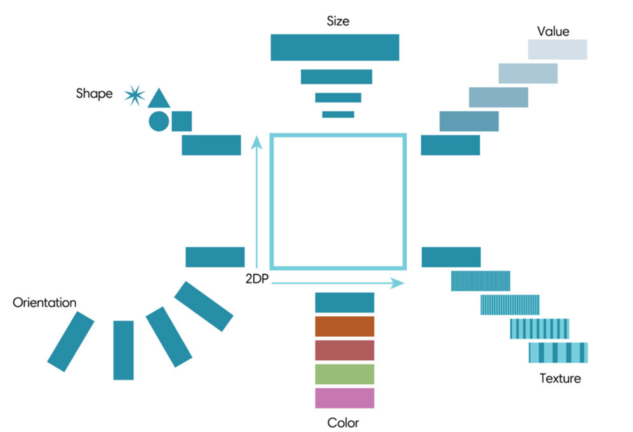


Fig 4: The eight retinal variables that provide a way to distinguish one object or data from each other.

The embodiments are separated into the two distinct diagrams because time could bias the placement of the embodiments. The distinction stems from an unclear definition of the word avatars. A universal definition of avatar has not arisen. Bailenson calls both a profile picture for a digital forum and a full articulated human-like representation in a game, avatar. In a profile picture, a user does not worry about how they control it of one moment to the next, it stays constant. While in a game, a user is constantly deciding what the character should do. Because of the difference of how real-time control plays into the perceptions of the representation, Bailenson separated them.

In the framework, Current VR Avatars is contained in a large area. This area is currently undefined and—based on my investigation—is much larger than Bailenson has originally depicted. As previously stated, I look to a term that can be more inclusive of the possibilities for user representation both digital and physically, and abstract and concrete.

RETINAL VARIABLE

Retinal Variables is a graphic system to create visual variation that displays different values of qualitative, quantitative and ordered information. Jacques Bertin, a French cartographer and theorist, defined this system in 1967 to give cartographers a way of using varying attributes to help with relaying information. There are eight variables in the system. The first two are grouped together as the 2-Dimensional plane, x and y. The following six are classified as color, orientation, shape, size, texture and value. Bertin states, "They form the world of images. With them the designer suggests perspective, the painter reality, the graphic draftsman ordered relationships, and the cartographer space (42)." The visual variables are not limited to these eight. In this theory, the two-dimensional plane is the start or base in which all systems are built.

For this exploration, I will not have the opportunity to explore all eight of these variables. While the 2DP is not a variable I explore directly it does add the foundation to Bertin's framework. I use shape, size, texture and color within this study. I create variations of each that users either control or are presented with in exploring the VR environment.

Two-Dimensional Plane

The plane is the area in which all variables lie. The plane breaks up into three properties: point, line, area. The point is a single location on the plane. Its location can be measured; however, it has no size or length. It is simply a mark. The line as the connection between multiple points quantifies a measurable distance but has no area. The third property is the area. An area has a measurable size and is made up of lines. Designers use the measurable ability of point, line, plane to give signifiers to viewers of how to read visual representations on the plane. In Bertin's explanation of the 2D plane, he uses groups of representations, diagrams, networks, maps, and symbols, to show how the plane can be implemented for conveying data. Once paired with types of construction, designers have a variety of representations to choose from, each with their own qualities.

Size

Size is the variation of one object's area to another. The perceived variation gives meaning to the difference between them. Size fluctuations is represented through differences in the x, y, or x and y properties of an object. This alters an object's thickness, length, or proportionate scale. While variations are easy to see, it is hard to discern from scale larger than 4 or 5 (71). Size additionally affects how other variables are perceived. At very small sizes, color is almost indistinguishable.

Texture

Texture is the pattern of marks within an area. Texture gives the sense of rhythm or density to an object. Users perceive rhythm from variation lined up next to each other. This is the Vibration Effect. The size of the mark used in pattern shows density. Like Value, texture does not reduce. At small sizes, users cannot perceive the texture. This works on both the size of the mark and the size of the separation.

Color

Viewers distinguish color by hue. The color variable is the perceived difference of one object's hue to another. Because color is perceived, the hue used is important for the viewer. When the 2D plane is white, yellow can be a difficult color to perceive. To give more variety to the color, saturation and value are additional properties. In equally saturated measures, the order is important. While a spectrally equivalent scale makes logical sense, setting the lighter color at either the beginning or end follows cultural norms (87). Colors have cultural qualities. In Western Culture, red can mean fire, heat or dryness. Green means vegetation. Knowing color symbolism is important when accessing the color variable.

Shape

Shape is the form of the object. While there are an infinite number of shapes, the shape must be recognizable as a way of disguising it from another shape. Shapes can be more basic like squares or circles or unique elements put into a pattern, icons or symbols, etc. The two applicable readings shape variations serve are:

1. to reveal similar elements, and, therefore, different elements

2. to facilitate external identification, through shape symbolism.

The first application, like the other variables, helps distinguish one from other. If one sees a square and circle, it would make sense that each object has different meanings. External identification is independent from representation but a collection of elements like textual description, shapes, measured values all play a role in helping a viewer identify those as parts of a graph.

Bertin states that he decided not to include the z axis as the ninth variable because it involves movement. Movement is a function of time and can dominate perception. In looking through his visual variables, signifiers that help a user to distinguish from one object to another is just as important in 3D space as it is in 2D space. Adding depth as a variable has the potential of expanding the properties of other variables as well. Texture could include ridges or bumps as elements of its pattern. Orientation can move towards or away from the viewer as well. In these additions, I would expect the number of steps the variable could take would reduce because the conveyed information is more complex. These eight, but subsequently nine variables, gave my investigation a way to classify the physical attributes a digital embodiment takes on. For my test, I explore how size, texture, color, and shape affect individuals in establishing social presence. Each test use these variables as a condition for what represents a user.

METHODS

Research through design

“Research through design recognizes the design process as a legitimate research activity, examining the tools and processes of design thinking and making within the design project, bridging theory and building knowledge to enhance design practices” (Martin 146).

Research through design is the approach I used in exploring presence in virtual reality. The secondary research from case studies informed my formal ideation used in developing my prototypes.

Case Studies

“The case studies is a research strategy involving in-depth investigation of single events or instances in context, using multiple sources of research evidence” (Martin 28).

The investigation used case studies to establish a visual and behavioral precedent to help me understand the current situation when it comes to digital embodiment in digital environment, both VR and VE. The companies I contacted for an in-depth interview were from researching for the case studies.

Interviews

“Interviews are a fundamental research method for direct contact with participants, to collect firsthand personal accounts of experience, opinions, attitudes, and perceptions” (Martin 102).

In the exploration into the visual representation of an individual’s digital embodiment, interviews allowed me to receive insight into what other groups were doing to acknowledge the problem or resolve it. They were important in giving me a deeper understanding of what people have tried apart from the limited scope that I was working with.

Prototyping

“Prototyping is the tangible creation of artifacts at various levels of resolution, for development and testing of ideas within design teams and with clients and users” (Martin 138).

Both in the exploration of digital embodiment and the final tool that gives access to my research, prototyping allows me to explore my concepts through actual tests and reflect on the principals being questioned. I built working prototypes to explore multi-user virtual reality environments and test what attributes they were accessing to establish social presence.

Experiments

“Experiments measure the effect that an action has on a situation by demonstrating a causal relationship or determining conclusively that one thing is the result of another” (Martin 82).

From the prototyping phase, user testing allowed me to measure the empirical non-design side of my research. I ran a series of experiments testing different forms of attributable representation of the users and then asked them to fill out a questionnaire. The 40-question questionnaire measured social presence. Following the questionnaire, I ran a short informal discussion with the groups to talk about the experiment and some of their perceptions.

LITERATURE REVIEW

SOCIAL PRESENCE

Defining and Measuring Social Presence: Contribution to the Networked Minds Theory and Measure

Frank Biocca, Chad Harms

Biocca, Harms build upon their initial definition of social presence where here they break their definition into the three levels I use in my investigation. They break down the Social Presence Theory and the shortcomings from the original psychologist, Short, Williams and Christie, in 1976. Biocca and Harms lay out their Networked Mind Theories which derives from their measure of Social Presence. The theory gets the concept of social presence to the point that it looks past co-presence, a necessary establishment but not the end, and closer to connectedness. While they frame their theory in telepresence and human-computer interaction, the theory gives my investigation a way to understand the complexity of the psychological theory and produce a measure to evaluate my experiments.

Towards a More Robust Theory and Measure of Social Presence: Review and Suggested Criteria

Frank Biocca, Chad Harms, and Judee K. Burgoon

Biocca, Harms, and Judee take the measure Biocca and Harms developed and use that to establish a need to expand the overall theory of social presence. They speak of possible areas in Human-Computer Interaction that social presence theory has a place to facilitate. They also propose possible scopes of future research using the theory. Their first areas of possible HCI research is using Social Presence theory to access design goals, social motivations of users, properties, and effects of telecommunication systems. The second area is to use social presence measures to assess performance of "social presence" technologies. The technologies include collaborative work environments, mobile devices, teleconferencing interfaces, agent-based e-commerce, speech interfaces, and 3D social virtual environments. Both HCI areas give my study additional context of how social presence can be used to explore and assess an area that affect designers and psychologist alike.

The Evolution of Social Presence Theory on Online Learning

Patrick R. Lowenthal

In this theory review on Social Presence, Lowenthal describes the major factors leading up to the state of where Social Presence is as of 2009. Social Presence transforms over time from being Social Presence to Cuelessness to Media Richness to Social Information Processing back to Social Presence. Each theory competes with the other. The definition of the theory has six interrelated but distinct definitions:

1. Presence as Social richness
2. Presence as Realism
3. Presence as Transportation
4. Presence as Immersion
5. Presence as Social Actor within Medium
6. Presence as Medium as Social Actor

Lowenthal looks to a way to use social presence to assess the value of online learning that utilizes collaboration. With online learning, there is another factor that is important and that is satisfaction. Saniye Tugba Bulu explores the effect of social presence and satisfaction when it comes to online virtual environments.

Place Presence, Social Presence, Co-Presence, and Satisfaction in Virtual Worlds

Saniye Tugba Bulu

In this study, Bulu looked how Place, Social and Co-presence are related as a way of satisfying students in virtual worlds and their immersive tendencies. Participants used Second Life to create Wikipages and posters in-game over the course of three weeks. They were also given the ability to enrich their profile over the course of the time. Bulu discovered the students who felt the most social presence were the most satisfied with their experience. The ones who felt more spatial and co-present had higher immersive tendencies. Bulu set up the study with little instruction to have students discover the bounds and limits of what was capable. In doing so, students were more observant of their environment and learned by doing. I use the interconnectivity of spatial and social presence to introduce users to a space. Through self-discovery, it helps users to feel more present in the space.

Exploring Self-Presence in Collaborative Virtual Teams

Rabindra Ratan and Béatrice Hasler

In this study, participants use the program UNIworld for a semester-long collaborative project. Ratan and Hasler asks the participants to answer self-reported questionnaires. They confirmed that self-presence and social presence are related. The study uses different levels of self-presence to assess the self-reported value. The parts were body, emotions, and identity. The Body level or Proto Self-Presence, was how well the digital representation integrated into the body schema. Emotions level or Core Self-Presence, is the emotional responses elicited form mediated interactions between self-representations and objects. Identity level or Extends Self-Presence is the degree to which someone's identity and self-representation align and share similar qualities. In the Identity level, there are possibilities of the Proteus Effect. Ratan and Hasler found that the proto and core level are distinct and both are positively related to design time of representation. They did find that when participants changed their representations, there was no positive correlation with self-presence. While agency of one's character helps establish self-presence – proto and core, Extended Self-presence has no effect on social presence. Proto and Core align with Biocca and Harms measure of social presence including behavioral interdependence and psychological engagement.

Measuring Social Presence in Team-Based Video Games

Matthew Hudson and Paul Cairns

While many video games offer a solo play through, more and more videos games offer a chance for people to come together and share an experience together either in person or online. To evaluate and measure the social experiences, Hudson and Cairns look at the measure Biocca and Harms created for Social Presence and altered the questions so it would apply to social presence in team-based video games. They ask similar questions of player awareness and identity, and actions that lead to competition and cooperation. This measure looks at a way of adaptation for media-specific measures. While Biocca and Harms' Networked Minds theory creates a foundation, Hudson and Caires expand the theory for greater reach.

COLLABORATION

Group Processes in Computer-Mediated Communication

Jane Siegel, Vitaly Dubrovsky, Sara Kielser, and Timothy W. McGuire

A 1986 study on how computer-mediated communication changed group decision making. At that time, research on behavior with computers fell into four categories – technology assessment studies, organizational studies technical capabilities studies, and social psychological studies. This looked at the fourth category by conducting a 3x3 study. The three conditions were face-to-face, computer-mediated anonymously, and computer-mediated identified. The face-to-face conditions were the fastest to reaching a decision but the computer-mediated conditions lead to great social equalization and uninhibited behavior. Groups made decisions that were closer to group consensus rather than dominated by a single individual. This study did not deal with Social Presence; however, in this task-oriented environment there is potential for balanced cooperation when the representation for users are minimal. In these experiments, Siegel et al. conducted the computer-mediated interaction using a text-only chat protocol.

Theories and Methods in Mediated Communication

Steve Whittaker

There are three main areas of Communication Theory: Bandwidth Theory, Cognitive Cueing, Social Cueing. Bandwidth theory is the idea that the closer the mode of communication is to face to face communication, the more efficient it will be. Little research proves this theory. The research showed the opposite, that when communication incorporates voice, it will be most efficient regardless if it was face-to-face or not. Cognitive Cueing looks more at the behavioral modes of communicating with another individual, like speech, gaze, gesture and backchannel feedback. This looks at how people use gestures to take turns; visible presence gives indication of one's availability to communicate; shared environments facilitate communication about said environment; and environments that allow for backchanneling increase conversation comprehension. The studies found take-turning and availability inconclusive, but strong evidence for interactivity and shared environments. Social cueing is the social attributes projected and received from others. This includes the idea of social presence. The theories associated with Social Cues include Content Differences; visible behavior leads to greater disclosure of information, Negotiation and deadlock; technologies that do not provide access to interpersonal information makes it harder for people to negotiate, and Participation and acceptance; technologies that limit access to interpersonal information and social feedback impede social processes. Research shows that Negotiation, participation and acceptance has little effect on social processes in task-centric situations. This leads to the overall conclusion that there is no real difference between face-to-face communication and mediated communication during cognitive tasks involving interactive technologies. Communication with high levels of visual information has little to no effect on the efficiency of the communication.

The Effects of Avatars on Co-presence in a Collaborative Virtual Environment

Juan S. Casanueva and Edwin H. Blake

Collaborative Virtual Environments, CVE, allow for users to join even when they are not co-spatially located. User have shown higher levels of knowledge transfer whilst in CVEs and improvements to learning and performing. Two things that affects a user's co-presence in the environment are avatar realism and functionality. Functionality, for this study, were simple gestures and expressions. Casanueva and Blake found more realistic avatars resulted in higher levels of co-presence. Avatars used for this study were either unrealistic, cartoon-like or human-like. Unrealistic avatars were block-based humanoids with eyes. Cartoon-like were characters like Dilbert. Human-like avatars had full articulation human characters with faces. Compared to static avatars, avatars having gestures resulted in even higher levels of co-presence. Casanueva and Blake used computer-mediated CVE and had all the participants in separate rooms. Each participant was a different type avatar. In doing it this way, users were not given the opportunity to explore and learn how to express themselves given the limited functions. The study does express the importance behavioral expression has for users in establishing presence.

DIGITAL EMBODIMENTS

The Effect of Behavioral Realism and Form Realism of Real-time Avatar Faces on Verbal Disclosure, Nonverbal disclosure, Emotional Recognition and Copresence in Dyadic Interaction

Jeremy Bailenson, Nick Yee, Dan Merget, and Ralph Schroeder

In CVEs, user realism is described in terms of avatar realism and behavioral realism. Avatar realism is how close to the human controlling it, it looks. This is also called form similarity. Behavioral realism is how close the movements and behavior represented match the controller, or behavioral similarity. Bailenson, et al. conducted a variety of studies with different levels of form and behavioral realism to see the effect of information disclosure and level of co-presence. The experiment is detailed in the previous section. The study concludes that voice communication resulted in high levels of co-presence and disclosure. In the abstracted emotibox condition, it resulted in high levels of disclosure but low levels of co-presence. This parallels Whittaker's computer-mediated study and how too much visual information affects disclosure of information. This includes how much emotion an individual expresses. In low representation environments, people emote more because they know it is not being represented.

Appearance and Task Success in Novel Avatars

Andrea Stevenson Won, Jeremy Bailenson, and Jaron Lanier

Novel avatars are representations that do not match the user's movements one-for-one. In this study, Stevenson et al. explore body transfer through the implementation of a three-arm avatar and the user's ability to utilize it. The appendage is explored through either biological or mechanical appearance and attached or detached. Biological detached avatars scored the lowest at the task and presence. Mechanical scored equally attached and detached. Stevenson et al. associated the lower scores to a feeling of dissonance because of the visual representation of the biological arm. As Whittaker points out in his study, when a task is involved higher visual information can inhibit the task at hand, so the higher representation of the arm may have fell into the "uncanny valley."

Toward Avatar Models to Enhance Performance and Engagement in Educational Games

Dominic Kao and D. Fox Harrell

In virtual environments and virtual reality, users can exhibit stereotype and bias based on their avatars. In this study, Kao and Harrell study the effect of a geometric shape avatar and a customized humanoid avatar have on players' performance and engagement. Participants chose the shape and color for the geometric shape conditions. For humanoid condition, participants customized their avatar through the Nintendo Wii Mii creator. Both conditions had participants progress through three different levels of a maze. The levels fostered computational thinking. Kao and Harrell used these representations to explore the effect of blended identities, or a user's projection of oneself into digital self-representation. Stereotype Threat motivated the exploration. Stereotype threat is the idea that users' representations prompt positive or negative outcomes based on their own social groups. For example, a woman performing low in math because her female identity is made salient. The results from the study showed players under the geometric shape condition performed better at the game and reported higher levels of engagement even though they reported lower connectedness with the avatar. This study shows how basic, non-realistic representations can positively influence a user's ability to understand and complete a task.

Leveling Up on Stereotype Threat: The Role of Avatar Customization and Avatar Embodiment

Rabindra Ratan and Young June Sah

Ratan and Sah take a similar approach to Kao and Harrell with adjusting how a player is represented to see the effect on their performance in a virtual environment. Ratan and Sah, use Nintendo's Wii Miis, as well. In this, they use gender bias as their condition. The all-female participants complete a math-based task after playing in a sword-fighting game on the Nintendo Wii. Females who were represented as a male avatar performed better in the task than the ones who were represented as a female. This study confirms the previous notion that the identity that is amplified through the medium has possibly negative outcomes for the individual. In contrast, users who customize their avatar have a stronger connection with their avatar and find it easier to embody the representation. This enhances the player's willingness to return to the avatar for future use. While stereotype threat can be reduced, it is harder for users to connect with their representation.

The Influence of Racial Embodiment on Racial Bias in Immersive Virtual Environments
Victoria Groom, Jeremy Bailenson, and Clifford Nass
Much like gender bias, avatars that indicate a race affect user's attitude and behaviors. Groom et al. conducted a study in an immersive virtual environment, IVE, utilizing VR. Participants were either in the condition where they had a mirror to see they were a certain race or they weren't and were either embodying Black or White avatars. In situations, where users embodied Black avatars, participants exhibited greater racial bias than by White avatars. This bias extended after the participants left the IVE as well. This study agrees with Ratan and Sah's study in which women perform better in math when embodying a male avatar. This study has serious implications of the effect of prejudice in virtual environments and means of reducing these effects.

VIRTUAL REALITY

Infinite Reality: The Hidden Blueprint of Our Virtual Lives
Jim Blascovich and Jeremy Bailenson
This book explores the many facets of virtual reality up to 2011. This book is the bases for my investigation as it expands on psychological ideas and how they have been explored in Virtual Reality. More importantly, this text states that a user's perceptions enter in VR with him/her, much like bias and stereotypes, and the experience in VR affects his/her perceptions exiting VR. Blascovich and Bailenson explore this idea of lasting effect with users embodying a cow within VR. They then checked back with participants for multiple weeks afterwards to see that many of them reduced their meat consumption. Similarly, to help teenagers learn how to save money, they put them into an environment where they embodied an older version of themselves to help encourage future planning. In the text, they list out six commandments to VR: 1) Make Virtual Reality work for you 2) Consider your virtual legacy 3) Mix the physical and the digital 4) Watch your digital footprint 5) Be wary of addiction 6) Look for yourself. The commandments are divided into a "yin-yang" where the first three are positive aspects of VR and the last are negative. This gives users, researchers, creators, a way to look at VR for both the good and the bad, and help establish a precedent that demonstrate previously explored concepts.

Research on Presence in VR: A Survey
Martijn J. Schuemie, Peter Vander Straaten, Merel Krijn, and Charles Vander Mast.
As VR is being used in psychological therapy, Schuemie et al. explores the research on VR effectiveness and the implications of presence. Schuemie et al. echo the same points Lowenthal did in his review on presence. They list how presence, especially social presence, is multi-dimensional and, given the current ways of measuring it, it is difficult to definitively state anything. Results start to show that VR is useful for subjective sensations of enjoyment like games but is less clear with task performance, emotional responses and phobia treatment. Of the various factors that researchers have stated to contribute to social presence, vividness, interactivity and user characteristics, have produced the most statistically significant results. Vividness is a much broader term and has results in a range of work, looking at field of view, to dynamic shadows, to olfactory cues. Vividness is closely related to clarity of information sent to one's sense, or sense fidelity. Interactivity is the extent to which a user can participant in modifying form and content in VR environments. Results shows interactivity through gestural inputs like body movement and head tracking contribute to presence. User characteristics are individual differences that have the potential of facilitating one's willingness to suspend their disbelief, which is necessary for experiencing presence. This explored through visual, auditory and kinesthetic representation systems. Visual and Kinesthetic showed the higher contribution

to presence. Through these expanded reviews of contributing factors to and effects of presence within VR, there is more to VR than presence. I agree there is more than presence; however, just as computer-mediated communication was explored in the 1980s, VR needs further exploration to see what is needed and what is desired. While self-reported measures are the only measures, it will be difficult to conclude that.

VISUAL LANGUAGE

Semiology of Graphics

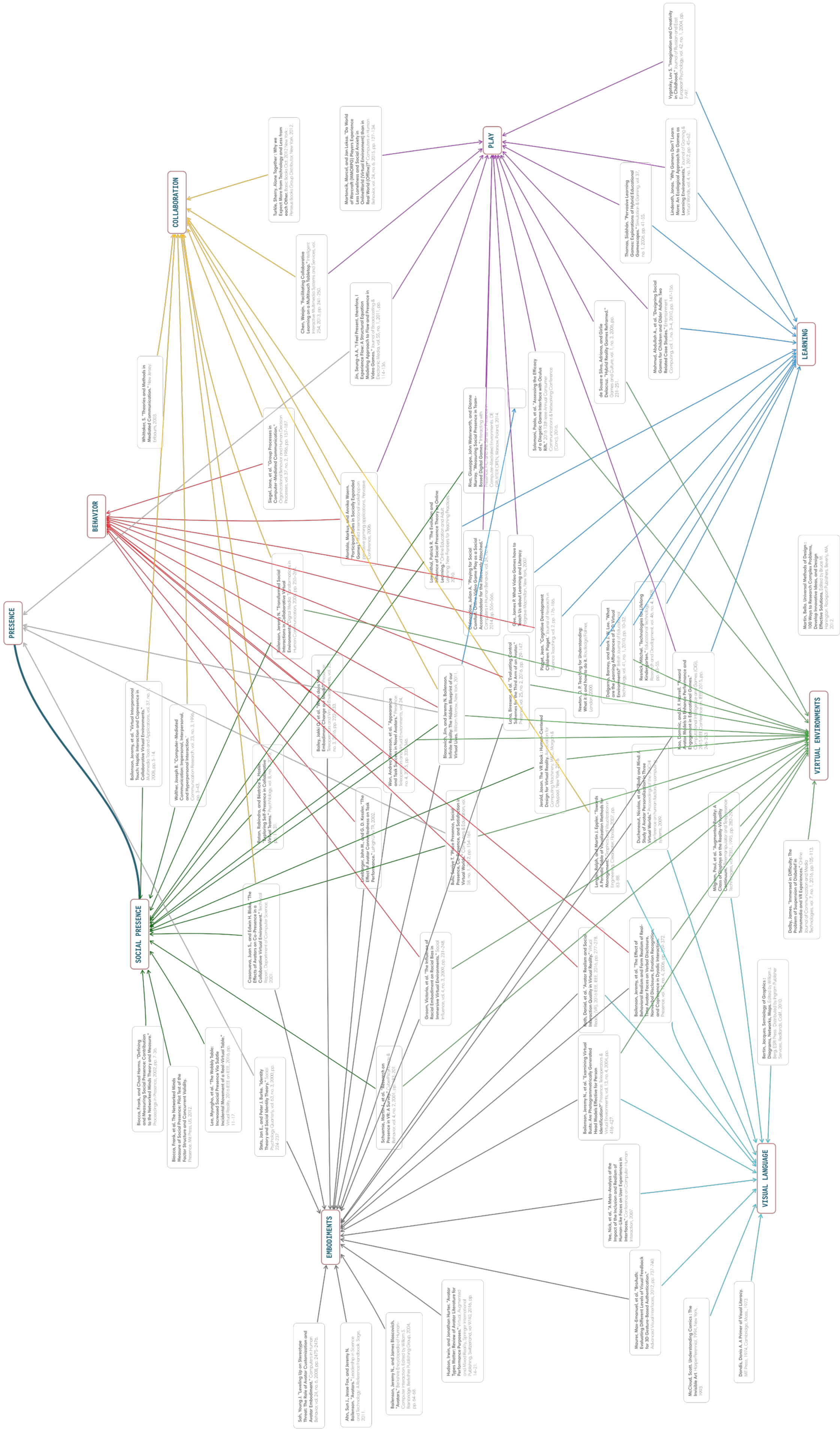
Jacques Bertin

A 1960s cartographer, Jacques Bertin explores representation of information and how that visualization leads to comprehension. His main retinal variables, as described in the previous section, display different types of information differently. These types of information are: association, selection, order, and quantity. While users can distinguish between all 8 variables when the information is associative. When information has a perceived order, size, value and texture results in the clearest message. This notion of variable usability builds into information architecture and can is now used in User Experience Design. Given that VR environments are digital representations of objects, all the assets represented in the space are possible data values. These values can utilize one or more of Bertin's retinal variables to distinguish and create understanding of an environment. The usage of the variables result in clearer visual representation and possibly contributing to social presence.

Understanding Comics: The Invisible Art

Scott McCloud

The idea of sequential pictures that tell a story goes back to paintings in Ancient Egypt. This is the basis that comic books are a series of concepts that move through a panel. This and every other form of art are part of the visual language. The visual language can be classified in how it is fixated between resemblance, meaning and retinal abstraction. McCloud refers to this as "The Big Triangle" this is one of the frameworks I use to classify my visual precedents. McCloud calls The Big Triangle as the vocabulary of visual language, and closure as the grammar. Closure is the way one frame is juxtaposed to the next to understand how the storytelling transitions. Therefore, closure is part of the invisible backbone of storytelling, and visual representation is the visible face. The two of them create connection between the meaning that is ultimately perceived by the reader. While McCloud's triangle and visual linguistics theories do not play a direct role into how I understand form in VR space, they give me a way to evaluate previous creations and understand why those embodiments took on the shape they did.


PLAY
COLLABORATION
LEARNING
BEHAVIOR
PRESENCE
VIRTUAL ENVIRONMENTS
SOCIAL PRESENCE
VISUAL LANGUAGE
EMBODIMENTS

PRECEDENTS

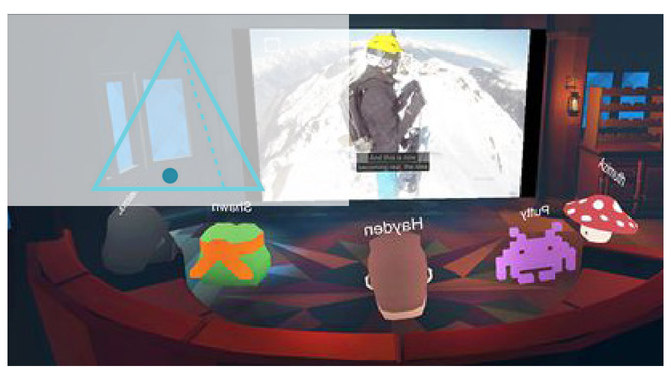
The easiest way to establish social presence in a digital medium is through social interaction. I explored a variety of VR and non-VR applications where social interactions are important. I looked at what their digital embodiments did, how they were made, and what sort of interactions users had. Additionally, I categorized that applications embodiment in McCloud's The Big Triangle.

Altspace VR

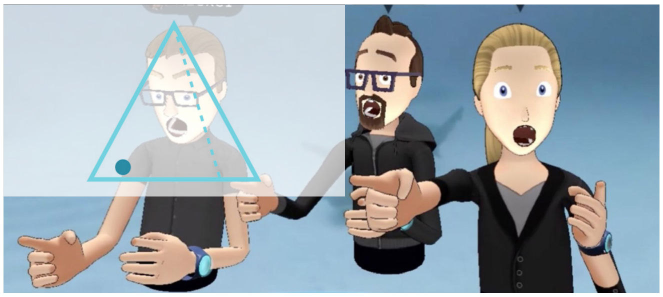
Altspace VR is an online communication platform. Users create avatars like the one in the picture to meet and talk with people in a VR environment. Users can chat, present, share files, and play games. While this is more of a social communication platform, Altspace VR is also being used for educational purposes. Users can create public events that anyone can join. Some are about getting people to watch streaming services like Twitch in VR, others are for language help like providing Spanish speakers with a friendly environment to practice English. Because of this application I included it in the education section. I'm including this in the precedents to look at how Altspace VR uses avatars and other representations to encourage social interaction between users and to note what kinds of social interactions.
altvr.com/

Oculus Social Beta

Oculus developed a social meeting application that gets users together to watch videos on Twitch or Vimeo and look at photos in a VR environment. What is interesting about Social Beta is that users pick an avatar before getting started. Instead of being a full humanoid figure it is a floating head and that head follows the user's head rotation. This gives other users some indication to whom they are speaking to in a conversation.
www.oculus.com/experiences/gear-vr/825923220795204/

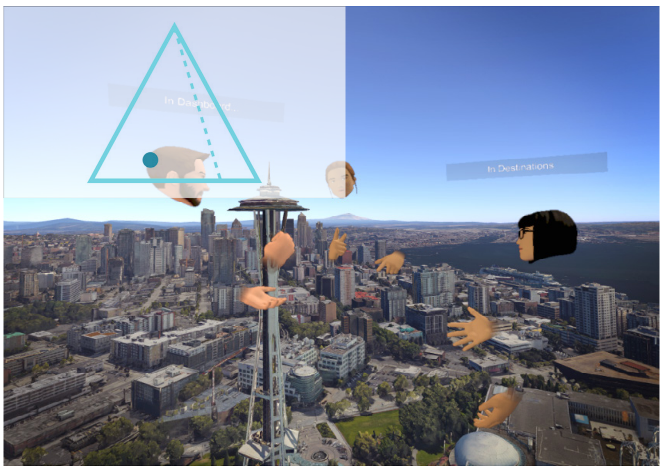


Facebook Social VR



Facebook Social VR built upon Oculus Social where it allows friends to come together in a VR environment. It also connects with Facebook to post, share, and view content from there. Social VR represents users as bottomless figures and uses the inflections and sounds in the user's voice to predict emotions like laughing, smiling, and surprise. The embodiments are built upon by pictures users have in their profile and then customized from there.
www.facebook.com/zuck/videos/10103154531425531/

Pluto VR



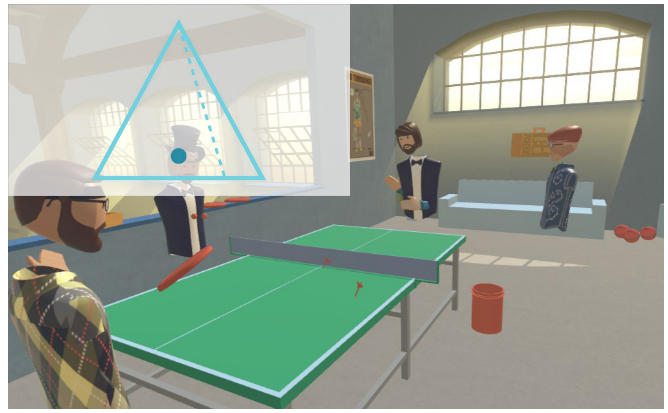
Pluto VR is an application that brings VR and AR to face to face communication. It gives its users a place to communicate, collaborate and connect with others from anywhere in the world, as if they were teleported together. Each user makes an avatar of their face. In the space they are represented by this face and two hands. Users can control finger gestures, like pointing or thumbs up, through buttons on the VR controllers. The position of their hand and hands are tracked through the headset and controllers. They also represent overall position in the space by using spatial room tracking. Blinking and mouth moments are automated to give a sense of life. Pluto VR, much like Google Hangout or Skype, is just a way to transmit the conversation can be overlaid into any other application for more targeted conversation. The default is a standard white space with gray gridded floor but is easily swappable.
www.plutovr.com/

vTime

vTime is a social network VR application that works cross-platform. Users create embodiments from wide selection of choices. From there, they can connect with strangers or friends. The application is built around talking to each other, so most environments have them conversing in a circle. There is no movement in the space except for slight gestural movement while sitting. Users are able to select gestural movements to perform as well, like dancing.
vtime.net

RecRoom VR

RecRoom VR is a game from Against Gravity. They list it is as a social club where users play active games with others from anywhere in the world. In the rec room motif, users enter in the locker room to customize their embodiments and then enter the play area where they can interact with others. The embodiments are disjointed heads and hands attached to a floating torso. The hands and head, like other VR applications, are tracked through the headset and controllers. The facial features are limited representation: no ears or nose. Also, the mouth perpetually has a smiling face on it. There is room tracking available but the movement is discontinuous through using the controller to teleport from location to location. There is a delay between each teleport.
www.againstgrav.com/rec-room/

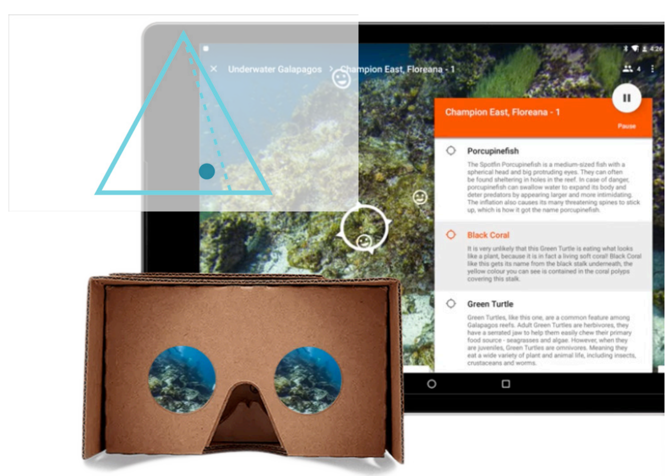


Labster

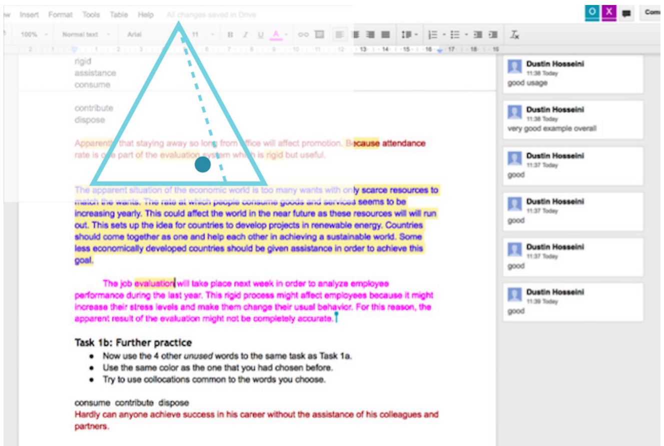
Labster is a tool designed to bring high-tech lab equipment to the hands of younger students to give them the experience of doing real tests without any risk. They use VR to immerse the students in lab spaces and allow them to run different tasks on equipment, as well as dive into experiments like PCR. Labster claims that when using the tool in conjunction with regular classroom methods, it increases the students understanding of the material by 101%. What I find interesting in Labster is how it allows a student to dive into experiments as well as conduct them in the VR environment.
www.labster.com/

Google Expeditions

Expeditions is an application that helps teachers take students on VR tours, like museums, underwater, and outer space. It has pre-built expeditions that have their own curriculum devised to help teachers build it into their lesson plan. What is interesting about Google Expeditions is that it links multiple users to one phone. The main leader is called the “Guide” and everyone else is called a “Follower.” The guide chooses the place and can pick from a predetermined list what is called out to the followers. This is represented by a white circle on the screen. While followers move around in the space, the guide can see in real-time what the followers are looking at represented with a smiley face, as displayed in the image. Seeing the followers’ location in real time gives the guide an indicator whether people are looking or distracted by something else. Unfortunately, in its current version, the followers cannot see where the other followers are looking.
www.google.com/edu/expeditions/

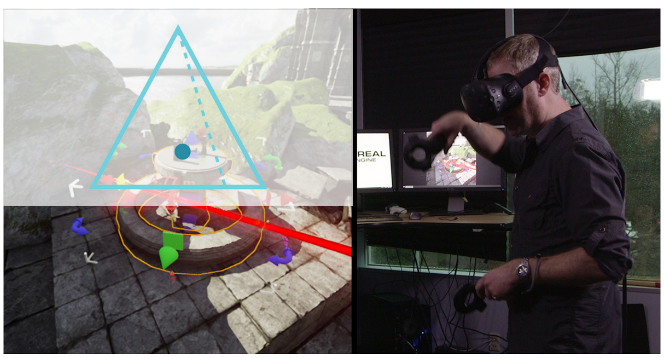


Google Drive



Google Drive is a collection of online productivity tools and file management. It ranges from Docs to Spreadsheets to Slides, a presentation editor. What is interesting about Google Drive and its tools is the ability to collaborate with other people. Any file or folder can be shared with anyone. In each file a user can see everyone who is currently in the document and where they are. This is represented by a colored cursor making to a color border on their Google Icon on the top of the page. Every comment that is left indicates who wrote it. For every version that is saved, a user can go through the history and see who added what when. This is an interesting archiving feature. While Google is not the only one that provides an online, or offline, collaboration service, I chose to point out Google because of the familiarity it has in the education field and to contrast the way other VR collaboration programs represent another user's presence.
drive.google.com/

Epic Games



Epic Games is a North Carolina based game development company that developed the game engine Unreal Engine. Unreal is noted for bringing "high-fidelity, interactive experiences to PC, console, mobile, VR and the Web" (epicgames.com). In 2015, Epic games added a VR editor to their Unreal Engine that allows game developers to edit the game environments while in VR. This gave developers the ability to utilize hand and head movements to do complex 3D actions for six degrees of freedom, while mouse input gives them two. This whole process helps save game developers time in the creation process as it also immerses the developers in the environment they are creating. Other immersive creation programs for designers and artist includes Oculus Medium and Google Tilt brush where people can draw and paint in 3D space.
docs.unrealengine.com/latest/INT/Engine/Editor/VR/

INTERVIEWS

After completing my exploration of visual precedents, I reached out to three companies that develop social VR experiences: Altspace VR, Pluto VR and RecRoom VR. To protect the privacy of the individual interviewed, I will refer to the interviewees by the application they work on. Each one designed a slightly different VR experience, along with different embodiments. While my investigation does not dive into true social situations — the primary focus is for people to talk and discuss ideas with each other— I looked at their applications to establish benchmarks. Higher social situations need more realism from embodiment, both formal and behavioral realism (Blascovich, 133). Therefore, socially centric applications have a better understanding of the realism required to facilitate social interactions between two or more virtual embodiments. I talked to the companies about how they designed their social VR experience, what they have done towards user testing with their embodiments, and how they see VR and social VR moving forward.

WHAT I LEARNED

VR as a social experience

All three companies saw the potential for VR as a social experience. Pluto VR equated its application to Microsoft's Skype or Google Hangout. This is a place for people to come together and discuss concepts together. It falls more on the teleconferencing side of communication. In the application RecRoom VR, they state how an application designed for people to play games like paintball or dodgeball has turned into VR meeting space. From time to time, a group of people gather around for a scheduled meeting. Altspace VR is a meeting space and is like a chat room. "People are generally meeting with other people to do things they might normally do: attend a comedy event, play a game, watch videos. People feel as if they are together and, for the most part, they bring their expectations and norms with them from their physical world."

People bring their social norms with them into VR. In Altspace VR, French users still greet each other by leaning in to kiss each other on both cheeks. If a phone rings during a meeting, people will turn around and say "Sssh!" In both room-size tracking and controller-based movement, users still have space bubbles. In Pluto VR, the interviewee demonstrated the visceral reaction you feel from people into your personal space. In Altspace VR, people expressed a similar feeling of awkwardness or connection related to people getting spatial close to each other. In situations where users try to leave their physical or grounded reality behind, less social norms seem to appear.

Digital Embodiments

All three of the applications explored a variety of embodiments. Pluto Vr started with a floating white mask with holes in it for eyes. Using head-tracking other users could distinguish who they were talking to from just the head movement. Altspace VR started with something simple like a sphere and eyes.They had an issue when they moved from slightly abstracted to human-like embodiments. Users experienced the uncanny valley. From the sphere with eyes to the avatar they call "Tie-guy" they have been exploring embodiments that fall in between. "These experiments showed us that the avatars did not have to look like the person in order to create a sense of connection and presence." RecRoom VR chose a floating torso, head, and hands for their characters because of the game play. Games like dodgeball and paintball need a torso to hit. "We felt people tend to show a strong instinct to personalize their character and aesthetic, and personalizing the torso gave the [digital embodiments] more personality. People seemed to like that."

Don't represent what you can't track. Some of their digital embodiment design decisions come from this idea. When a VR scene represents a body part that is not tracked, it is Inverse Kinematics. This is when the program uses two other points, like a hand and head to represent an unknown body part, like an elbow. Pluto VR describes the player disillusionment with the space that results from poorly tracked representations. He spoke of elbows pointed in wrong directions, legs inside of another. To avoid this, they and others have limited their human-like embodiments to something less fully human.

VR as a growing platform
Recroom VR states, "I think [VR] will become a part of our daily life. Ten years ago, no one had a smart phone. Right now, no one leaves their house without one." Altspace VR states their VR users help field the non-VR users' questions about the technology, and they help those without hand tracking to experience the space. VR users demonstrate this in a presentation by holding a marshmallow up to their face to allow them to "eat" it. Pluto VR sees their application and similar ones as a way for people to converse. Methods like video conferencing will become a way of the past. People will move to interacting within these virtual environments.

FINDINGS

Social VR provides a place for social interactions to occur, either as the primary purpose or as the byproduct. Pluto and Altspace stated that realism is not quintessential to establish presence but for their applications they felt like participants desired realism . The research follows that in high social situations, a higher sense of realism to facilitate communication is desired. As the social interaction moves into a task-oriented environment, the need for form realism should lessen. The need for behavioral realism is still important, though. To follow the mantra, "Don't represent what you can't track," I can only represent a single tracked point, the head. These interviews gave me additional information about the idea of inverse kinematics. When the embodiment representation breaks the illusion or depiction, even the behavioral realism can fail. In my studies, I, too, began with abstracted representation, like Pluto and Altspace. I, however, looked at how visual attributes affect perceived social presence.

EXPLORATIONS

INITIAL FRAMEWORK IMPLEMENTATION

I began my research by looking at Bailenson's Representation of Human Embodiment. I used the breakdown of visual representation to dive deeper into the area that he refers to as Current VR Avatars. I looked at what current games and digital areas use to represent players and users to create this representation breakdown. I ranked the representations on degrees of form similarity to the user.

On most webpages like Google or Wikipedia, users have zero forms of digital representation. Users have no perception of how many users are visiting the page with them at any given time. In VR situations, beginning A-Frame examples and 360 viewers, like SphereCast, are the same way.

Current digital environments often use minimal representation to indicate presence. Google Docs is an example that uses traces of location. When people are viewed over a network, users can get idea of where other users were mere seconds before. This is due to the latency of a network connection, but those traces give users the perception of other's presence on the page.

Primitive Objects start to address 2D and 3D form. These representations are seen in early video games like Pong or Pac-man. When a user is represented as an array of objects it has the potential for human-like, or humanoid, representation. An array of objects is based on using an array of primitive objects. When the same object is used, like a cube, the array can look like a human using the arrangement and different scale to depict a head, body and legs.

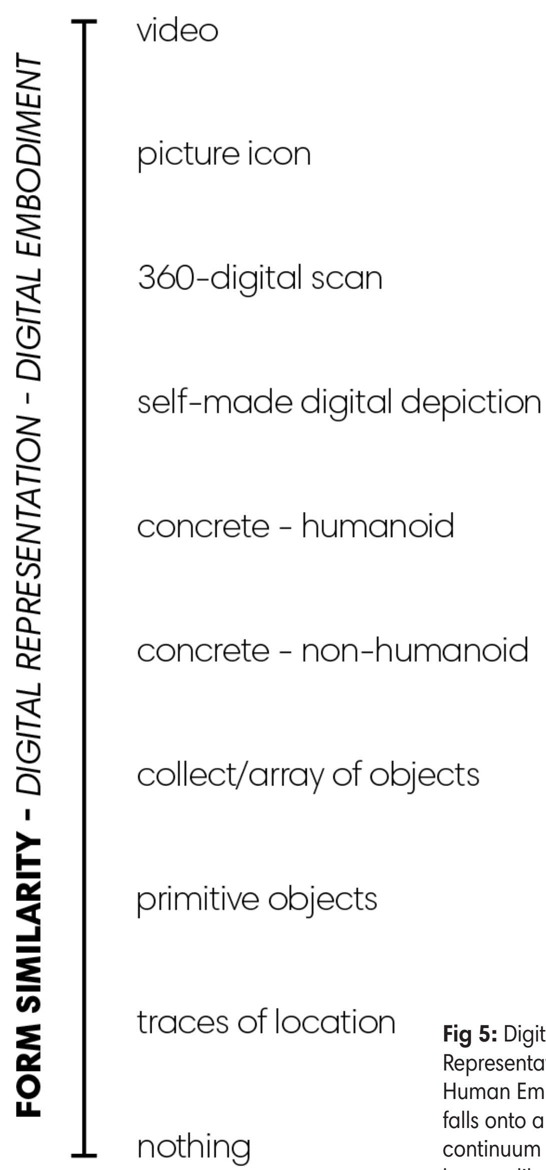


Fig 5: Digital Representation for Human Embodiment falls onto a continuum from less human-like to more.

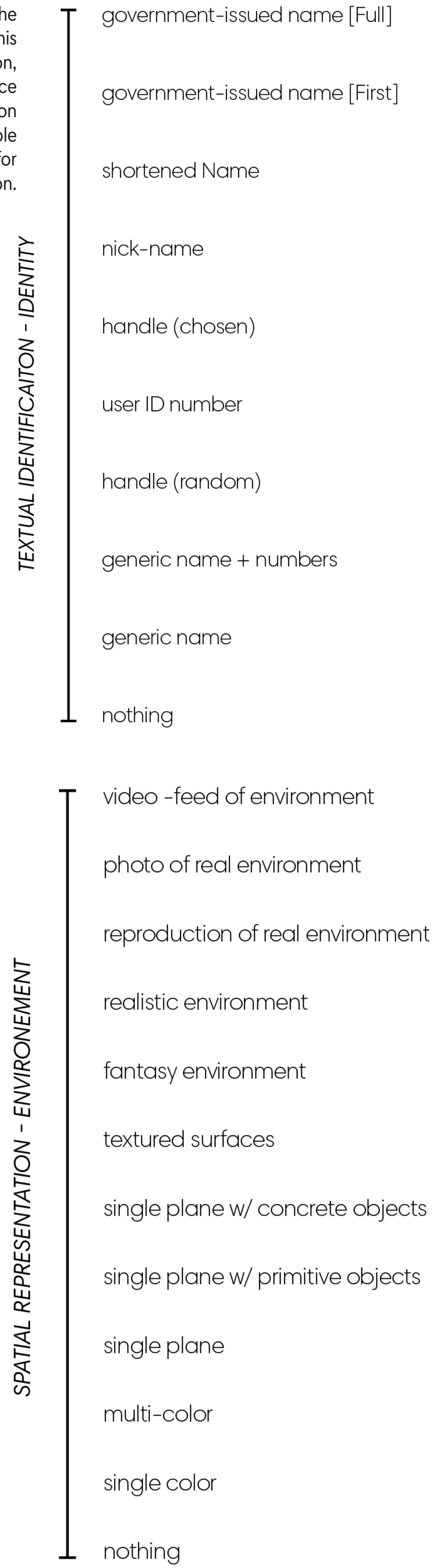


Fig 6: Whilst outside the scope of this investigation, text and space representation are possible avenues for exploration.

Minecraft does this with their avatars to make the users and the cubic environment to similar. The cubes can be less organized and more abstract where the users are asked to interpret their representation more. Concrete representations, much like the humanoid array of objects, can be identifiable but not human-like. An example of this would be like animals or just game controllers.

A humanoid representation suggests something more generalized or iconic. This form of representation is common in many virtual environments including video games, like Mario. Players are given little to no way to personalize their representation. In this way, it is kept iconic. Google Expedition depicts its users in the same fashion, by having every student's gaze represented as a smiley face.

Self-made depiction is when a user can customize the representation to feel more familiar to them. Users can do this with Nintendo Miis, Recroom VR, Pluto VR and many more. As more users enter the space there is a need to distinguish one from the next.

A 3D scan is not common for digital environments, but I wanted to include it in the scale to suggest this possibility for users to be represented in a digital environment. This falls below picture profile and video because the current technology does not allow for the form similarity to be as great as a picture would be. One study shows 3D scans of someone and a picture. Participants recognized pictures of people with greater accuracy over virtual 3D scans (Bailenson, "Virtual Busts" 424).

Picture and video are both in Bailenson's original framework. I included them in the ranking to tie them back to his framework and to add them as a consideration of digital embodiments that users project themselves into. In current social media platforms, like Facebook, Twitter and Instagram, users have profile pictures to distinguish one person from the next.

OTHER FORMS OF CLASSIFICATION

While visual language used for representation grounded my investigation, I wanted to include in the exploration phase that I started with textual and spatial representation. I included these classifications to give future insight into the way that users and space tie together in terms of visual representation. This also gets into the idea of proximity and how an environment and user can change depending upon the context and situation.

FORM VS BEHAVIORAL SIMILARITY

Taking the categorical list of degrees of form similarity for digital embodiments, I speculatively placed them against their behavioral similarity. This is to look at how digital embodiments have a degree of form and behavioral realism and to help specify areas of my investigation. Bailenson split his framework into real time and non-real time embodiments. Because of that I took pictures off this chart. If these were split into animated and static representations, pictures would take the place of live video. For my investigation, I will be exploring the lower end of this framework because of the lack of research in this area and because the research I have found shows there is potential in exploring a more generalized form.

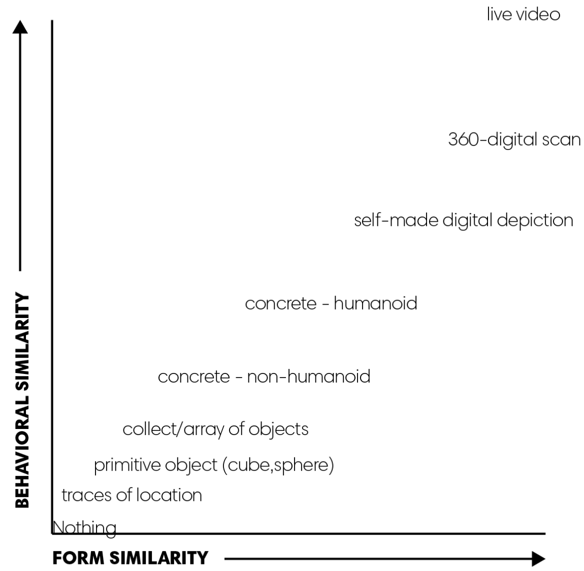


Fig 8: Digital representation breaks into two segments: form similarity and behavioral similarity, both can help establish presence.

INITIAL SKETCHES

Initially when I started sketching possible abstract shapes, I took a more scientific approach to representation. I divided the primitive objects into physical states: gaseous, semi-solid, and solid. The solids were where I included what would be classified as primitive 3D objects: cube, sphere, cone, cylinder, pyramid. I moved away from this division of the objects because they did not clearly connect to the form and visual language already explored in design scholarship. Instead, I focused on primitive objects.

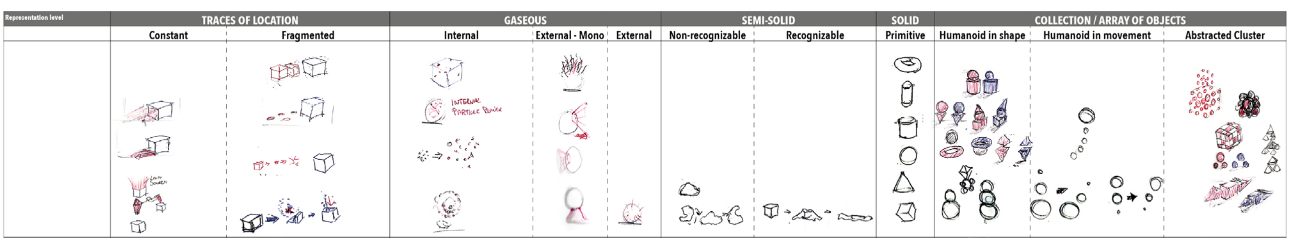
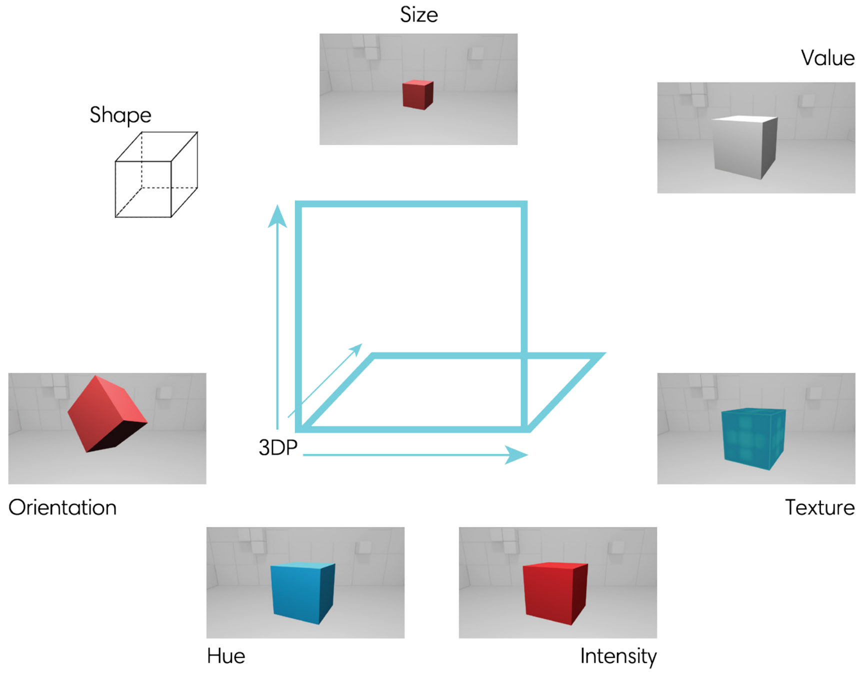


Fig 9: Initial sketches gave insight to a variety forms abstract digital embodiment could manifest as. This gave way for viewing them as primitive objects.

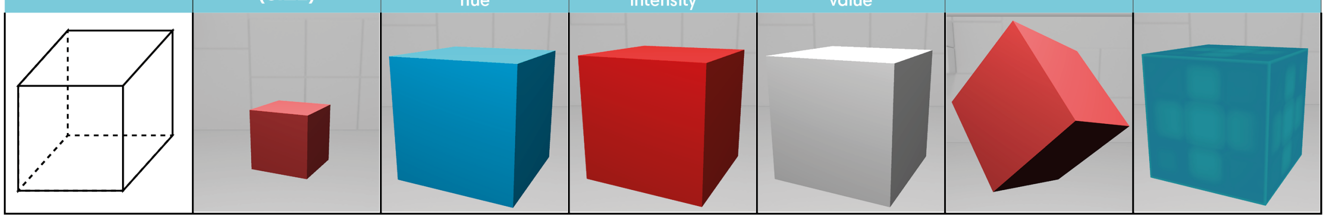
PRIMITIVE OBJECTS

The most primitive shapes: circle, square, and triangle. These shapes are the building blocks to any physical form (Dondis, 45). These are general forms taught in school to kids. These are the foundation for three-dimensional shapes, as well: sphere, cube, pyramid. Toys, like LEGOs or Mega Blocks, teach kids how they can build anything from a modular basic shape. In 3-D modeling programs like Maya, 3DS Max, and Solidworks, spheres, cubes, and pyramids are some of the basic forms given to users. In GUI based programing languages, like Processing, shapes are referenced as 2D and 3D primitives. With this common use of primitive shapes in mind, I used these as my starting shapes to explore digital embodiments. I included all the primitive shapes commonly found in 3D modeling programs: Sphere, Cube, Cone, Cylinder, Pyramid and Torus Ring. Like Dondis said for 2D primitives, these shapes can make anything humans can imagine.

Fig 9: Using Bertin's Retinal Variables, I could classify testable material attributes which became conditions of my user tests.



MATERIAL ATTRIBUTE						
SHAPE	SCALE (SIZE)	COLOR			ORIENTATION	TEXTURE
		hue	intensity	value		



RETINAL VARIABLES

Jacques Bertin refers to shapes as 1 of his 8 retinal variables. His other variables are size, value, texture, color, orientation, and x and y plane. Given that in VR everything is three dimensions, I included the z dimension as part of the variables. An object's x,y,z coordinates relate to their position in space and is controlled by the users. Since this is not a static variable but one that updates frame by frame, I did not look at their position in space as one of the visual variables that distinguish one user from another. The remaining 6 variables played a role in visualizing the users. This leaves size, value, texture, color, orientation, and shape. Color divides into three parts: hue, value, and saturation. In Bertin's framework he lists color to refer to an object's hue and has value as a separate variable. Therefore, I added in the other part of color, saturation. I grouped all three parts into the category of color but accessed them as separate variables.

BEHAVIORAL VARIABLES

Behavioral variables are things that users can utilize to project their own behavior into the
Behavioral variables are things that users can utilize to project their own behavior into the
space. Bertin's variables lacked movement and time based exploration, so I've included these as variables for further exploration given that the z-axis is added in VR. Bascovich and Bailenson have explored behavioral realism through the research done at VHI; however, since my exploration is abstracted down to primitive shapes, I also abstracted my behavior down to simple movements. I broke movement into three parts: speed, rotation and flexibility.

With more research into VR, I believe the behavioral attributes that users project into the environment will be expanded. I define these variables to lay a foundation for continued exploration.

After behavioral attribute, I included multiple. The multiple category is when there are more than one of the primitive objects. The objects start becoming a collection of objects, as compared to a single entity. As discussed earlier, the array can be concrete or abstract. A concrete configuration is an array that would appear to be representing something real. For example, if three spheres stack on top of each, in Western culture, that resembles a snowman and therefore something more human-like. Two spheres on the ground, however, suggest more abstract representation.

In the chart below, I begin listing out possible differentiating values for each variable for a given shape. For hue, I start with warmer and cooler. Knowing each one of these values has a possible culture perception, I list that in the map following this chart. Certain variables do not have a certain shape. A sphere does not have a perceived orientation when it is the only variable displayed. When portrayed in combination with others there are possibilities for a perceived orientation, but it could conflict with the behavioral attribute of rotation.

PLANNING FOR EXPERIMENT

These visual and behavioral qualities are important to my tests because they allow users to project their perceptions into the virtual environment. Because I am not giving user's representation humanistic forms and expressions, I am relying on cultural perceptions to create distinguishable results. From here I used this knowledge and frameworks to test out these variables to see their effect on establishing social presence.

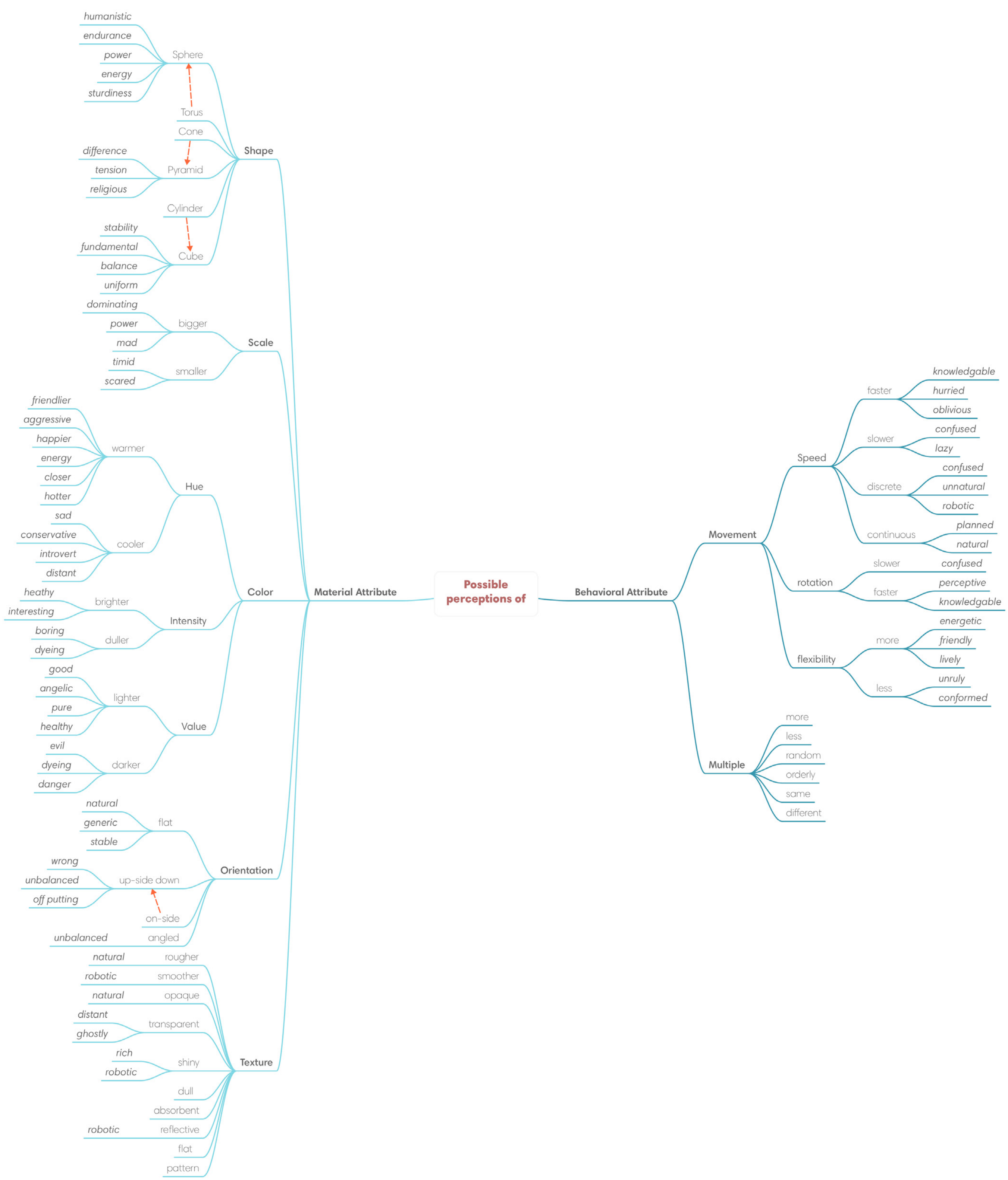
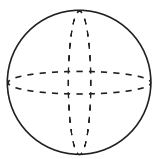
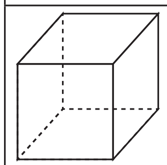
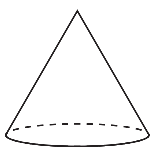
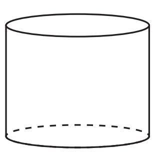
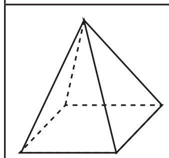
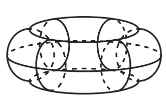


Fig 10: In dealing with material attributes of abstract shapes, I must consider possible perceptions of those characteristics.

Fig 11: When combined with 10 primitive shapes, Bertin's variables expands into a matrix that is used for user testing.

MATERIAL ATTRIBUTE							BEHAVIORAL ATTRIBUTE			
SHAPE	SCALE (SIZE)	COLOR			ORIENTATION	TEXTURE	MOVEMENT			MULTIPLE
		hue	intensity	value			speed	rotation	flexibility	
	bigger, smaller fatter, thinner taller, shorter	warmer, cooler	brighter, duller	lighter, darker		rougher, smoother opaque,transparent shiny ,dull reflective, absorbent pattern, flat	faster, slower discrete, continuous	faster, slower	more, less	more, less random, order same, different (see material attributes)
	bigger, smaller fatter, thinner taller, shorter	warmer, cooler	brighter, duller	lighter, darker	flat,angeled	rougher, smoother opaque,transparent shiny ,dull reflective, absorbent pattern, flat	faster, slower discrete, continuous	faster, slower flat spin, roll over	more, less	more, less random, order same, different (see material attributes)
	bigger, smaller fatter, thinner taller, shorter	warmer, cooler	brighter, duller	lighter, darker	upside, right-side up rolling on side, angled	rougher, smoother opaque,transparent shiny ,dull reflective, absorbent pattern, flat	faster, slower discrete, continuous	faster, slower flat spin, roll over	more, less	more, less random, order same, different (see material attributes)
	bigger, smaller fatter, thinner taller, shorter	warmer, cooler	brighter, duller	lighter, darker	right-side up, rolling on side, angled	rougher, smoother opaque,transparent shiny ,dull reflective, absorbent pattern, flat	faster, slower discrete, continuous	faster, slower flat spin, roll over	more, less	more, less random, order same, different (see material attributes)
	bigger, smaller fatter, thinner taller, shorter	warmer, cooler	brighter, duller	lighter, darker	upside, right-side up rolling on side, angled	rougher, smoother opaque,transparent shiny ,dull reflective, absorbent pattern, flat	faster, slower discrete, continuous	faster, slower flat spin, roll over	more, less	more, less random, order same, different (see material attributes)
	bigger, smaller fatter, thinner taller, shorter	warmer, cooler	brighter, duller	lighter, darker	right-side up, rolling on side, angled	rougher, smoother opaque,transparent shiny ,dull reflective, absorbent pattern, flat	faster, slower discrete, continuous	faster, slower flat spin, roll over	more, less	more, less random, order same, different (see material attributes)

PROTOTYPE

PLATFORMS

Unity3d
Unity3d is a cross-platform game engine that was initially released in 2008. In 2017, they are version 5.6. They support 27 unique game platforms. As of a study done by SourceDNA, in quarter one of 2016, 34% of the top 1000 free mobile games were made with Unity. Due to Unity's pervasiveness into the mobile platform and its ability to create for VR, I used this game engine for my prototyping. In addition, I had a year of prior experience working with Unity3D.

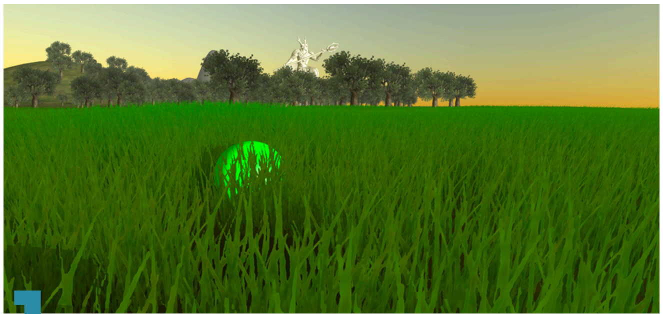
I programmed primarily in C# for these prototypes using Unity3D's libraries. I used Unity3D's MonoDevelop to write my code because when writing in C# it displays possible lines of code. Because of the way Unity3D compiles the code, I found writing everything in C#, as compared to Javascript, more conducive to having different scripts connect with each other which resulted in less errors. Upon building, all code was compiled in C++ to be opened in Xcode and rebuilt for an iOS device.

Photon Unity Networking
Photon Unity Networking, PUN, is a multiplayer platform for Unity that allows for connection over the internet. It supports real-time cloud hosting and is cross platform. I chose this platform over creating my own, Unity Networking and others because it was free and easy to use. I am not a network programmer and needed a utility that allowed me to start prototyping. PUN allows for up to 20 concurrent users at a given time, under their free plan, and 1,000 on their most expensive plan. For my test, I used the free plan. They provided a series of tutorials and demos that gave me the flexibility of creating my multiuser prototype easily. I chose a Client to Server structure for my test, instead of a Peer to Peer because of the ease of connecting to the room. In a Peer to Peer system, I would need someone to host the room and everyone else to be able to see the host. The way I have my client to server network established, the first users creates the room and every user following joins the already created room. The connection process is seamless.

Google Cardboard
Google Cardboard is a cardboard head mounted display released by Google on June 25, 2014. It uses a mobile device as the display screen. VR enabled apps use the device's accelerometers to know when a user turns their head. VR enabled apps create a split screen, left and right, view and the cardboard has 2 45mm focal length lenses to relay the stereoscopic view to each eye. Each side accounts for barrel distortion for each image to counter the pincushion distortion from the lens. Google released the build plans for these devices and third party manufacturers build their own version.

I chose to use a Google Cardboard over the HTC Vive or Oculus Rift because of cost and resources. The department had a limited quantity of Vives and Rifts. For me to test a multi-user prototype for this exploration, I needed multiple headsets, VR-capable computers, and a big enough space to set everything up. Because my investigation was about simplifying down the VR process, I felt using a simplified VR headset would be adequate and appropriate.

iOS Device
iOS is the operating system for mobile Apple devices, iPod, iPhone, and iPad. All three of these devices have accelerometers that allow them to run VR. For my initial tests, I used an iPhone7 Plus. For all my user testing experiments, I used an iPod Touch 6 Red edition. While a bigger and higher resolution screen results in better clarity and lower potential of nausea or sickness, I could check-out multiple iPod Touches from my department. This is not the case for iPhone7 Pluses and Android devices. Having multiple devices of the same type was an important constant for my test.



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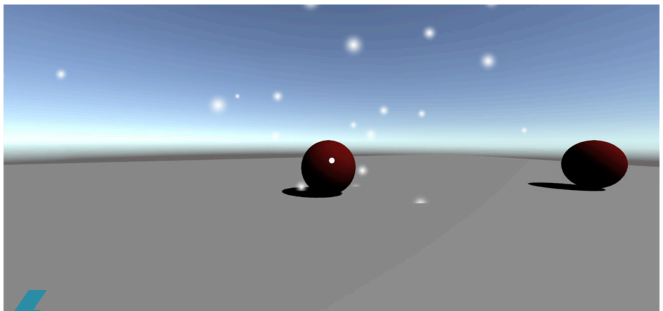

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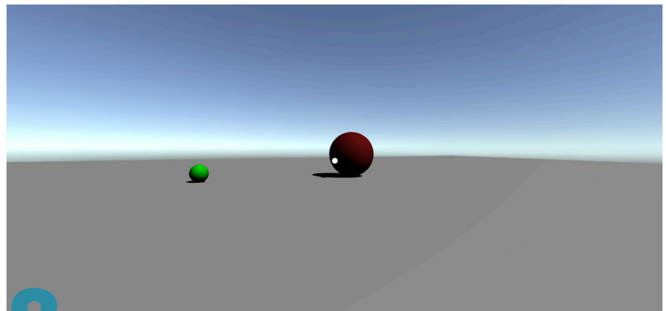

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TEST VARIATIONS

This test allowed me to enter the VR world and try out a physics with a primitive shape. I used a sphere initially. I established the code I needed to link the camera with the digital embodiment, DE. I also created basic controls for moving the sphere. The world had realistic grass, a pond, trees, hills, ground textures, wind, and a sun. One of the reasons for this was to see how the iOS device handled the demand for higher graphics. From my observation, it performed fine.

The issues with this test was the sphere would slide in the world without the user moving it—on flat and uneven terrain. There was no goal in this environment. A user could just roll around. The environment ranked too high on the realism scale, given what I was using for the DE.

Full descriptions of each test are in Appendix A. Tests that coincide with a variation change are marked.

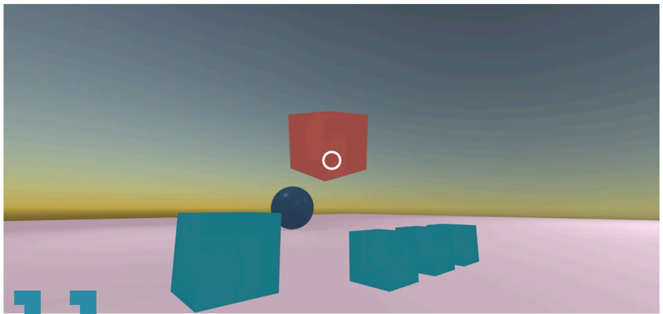
1. **Multiplayer**
   From this point on in the test, I included multi-player. I added Photon Unity Networking, PUN, to the scenes and I had players join over a network. They would enter as different colored spheres. From observations players would start playing a game of hide-n-seek or other find/search games.

   At this point in the development I let users speak to each other during use. Common questions were "Where are you?" and "Are you the [color] ball?"

   At this point, there was still no task in the environment and I did not resolve the sliding issue. Users' movements were not tracked well in the space and their movements were discrete. Play would appear to be "laggy" to each other. If a player was disconnected they would come back as a different color sphere.

2. **Reticle addition**
3. **Use of walls (invisible)**
4. **Better movement (less slide)**
5. **Plane space environment**
   At this point in my test, I moved away from the realistic forest environment. I created an area that was just a simple plane. This becomes my test area for trying out different inputs and mechanics until I landed on my experiment environment.

6. **Gaze-depicted input**
7. **2-D hub screen**
8. **Multi-player with gaze input**
9. **Multi-player with box**
10. **Switch to newer GVR SDK**
11. **Selecting/Moving/Stacking boxes**
12. **Instantiating boxes/smashing into boxes**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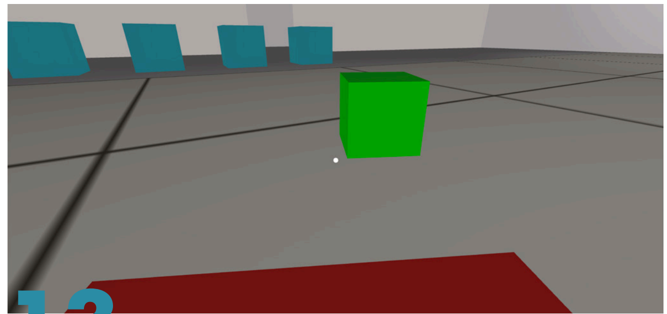
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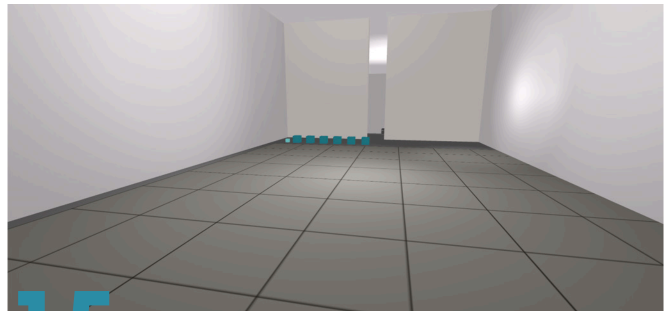
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13. User became a box

This variation and the one following happened almost at the same time. I decided, given that it was a mechanic change and a user embodiment change, to keep them separate. In this variation, I changed the users to boxes. This was because of the cultural perception that boxes are workmanlike, and it is easier to see when a user rotates their head.

The initial problem with the box was when I linked the boxes rotation to the user's head movement, the box skidded across the plane. This was because the box had a collider on it and so did the plane. If the box sat level on the plane when it moved, to reflect a user looking down, the lower edge of the box would try and go past the ground plane. This forced the box to move unnaturally across the plane. For the time being, I turned off this feature.

14. Look and do puzzle – Big

After I deemed the building blocks to be too difficult, I looked at another task-oriented environment. I created an environment where the users would go up a ramp to view a configuration of boxes on one side of the wall and then try and move the boxes on their side to the same configuration. The idea for this environment was to give users the ability to discover and complete the task if they wanted. Seeing other people completing the task might encourage them to participate. I added the wall and ramp to entice people to discover the task but also to encourage movement around the space.

The issue that I ran into with this environment was going up the ramp was too difficult. At this point, I still had the full head tracking turned on for the user cube and it made it difficult going up ramps. Even after I turned off the head tracking, it wasn't consistently easy, so I considered an alternative.

15. Look and do puzzle - Small

Since the previous environment was too difficult to move around within and discover the puzzle, I created a ramp-less environment with walls separating the user from the answer to the puzzle. Users would start in the environment with seven boxes lined up near a gridded floor and near a slit in the wall that they could move through. Once they moved through, they would see a large-scale replica of the room they just came from. Users could then travel back through the opening in the hole to push the boxes to the correct squares. After users moved all the boxes into the correct spot, a message saying "COMPLETED!" appeared on the wall.

16. **Timer**
17. **Deleted the "look" side - added lights**
    After some testing, I realized that the timer and going from one side of the wall to the other was not conducive to the environment. To make the objective simpler, I added green lights over the appropriate squares on the grid. To give users feedback on their movements, the boxes turned green when on the correct square. In the previous tests, there was one smaller cube that was different than the rest. That cube had a specific square to enter while the rest could be in any square. This still held true for this test.

    At this point, I began preliminary testing of my protocol for my test. All variations after this point were either fixes as results to bugs or explorations for possible tests.

    The next section details conditions of the test.

18. **Changed objects to spheres**
    Both the users and the objects to push in the environment were cubes. Users commented that the cubes were too difficult to move and detracted from the environment. For ease of pushing objects in the space, I switched the objects to spheres. This created a visual distinction between users and objects. The spheres remained the same color as before, light blue with a light texture to help recognize that it is rolling.

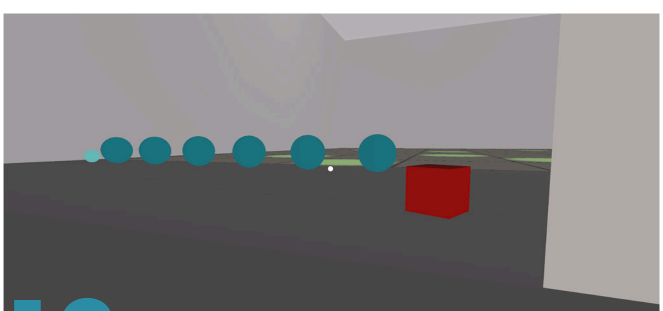
19. **Added a mirror**
    Since my initial tests, I had the stereoscopic camera that is a user's input into the VR environment, situated two units above the user's cube. The idea was for user to be able to look down and still see themselves. In preliminary tests, users did not always understand that they were a cube. To help with this and ultimately establish self-presence for the user, I added a mirror into the space. The mirror ran ¼ of the wall near the starting area for every user. I will discuss the results from the mirror in the findings section.

20. **Better push movement**
21. **Spectator View**
22. **Left-right movement tracked and translated**
    As I have previously stated, I had difficulty translating user's head movement to reflect in the user's cube. This was because I was trying to track X, Y, and Z head rotation. The X and Z rotation caused the cube to collide with the ground plane and move across the floor on its own. This created an uncomfortable sensation for the user. In preparation for the first experiment, I turned on the Y rotation, while keeping the X and Z rotation off. This projected the user's left right head movements onto the cube. This helped other users understand their movements.

23. **Buttons - get big or small**
    Looking back at my matrix of the various variables and possible ways of representing it, one was scale. This tests gave users the ability to look up and click either a "+" or "-" to change their scale. One click of the "+" increased the user's scale from 1 to 4. A click to the "-" would bring it back to 1. Another click would bring it down ¼ size.

    One issue that arose in this test was when users got down to the smaller size. If a user pushed themselves into the center of the mirror, they would fall through the floor and off the map. The other way to get them back is by restarting the application. I was unable to resolve this issue.

24. **Buttons - get brighter or darker**
25. **Proximity depicts Hue variation**
26. **Full head tracking (up, down, left right)**
    One of the main issues I had with head tracking before was the cube colliding with the floor. In this



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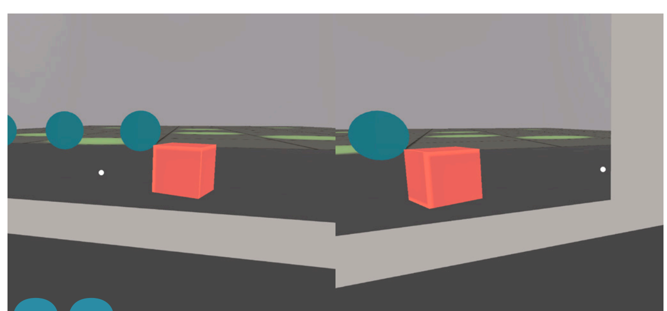

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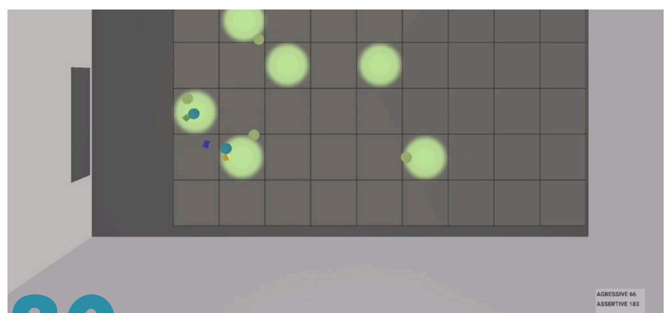
test, I lifted the cube off the floor three units, and let it share space with the camera. This prevented the ground and cube from colliding and full head tracking was made possible. In this test, a user could not look down and see themselves. This made the mirror was more important than previous tests. Observations and results from my findings will be in the following section.

27. **VR hub screen**
28. **Better push movement**
29. **Color changes**
30. **Behavior Chart**
    From my observations, I noticed the same general behavior: passive, assertive and aggressive. To help record the instances of these behaviors, I added a chart that only appeared on the spectator view. The chart was be the sum of the instances of all users during any given session. This appeared in the lower right-hand corner of that screen.

31. **Front face - lighter color**
    For this test, to visualize what way a user is facing to everyone else in the space, the front face of the user was a lighter color than the rest. The application did this dynamically on users joining the testing room. The color's value brightened by 20%. Observations and results from my findings will be in the following section.

32. **Avatars are spheres**
    For my last variation, I switched the users back to spheres. For this test, I added a texture that still gave users an idea of everyone's "font face." To keep with the previous tests, all users floated three units off the ground plane. I wanted to keep that constant between the last three tests. I also ran into the issue that the sphere would roll on the ground, separate from the user's head movement. Observations and results from my findings will be in the following section.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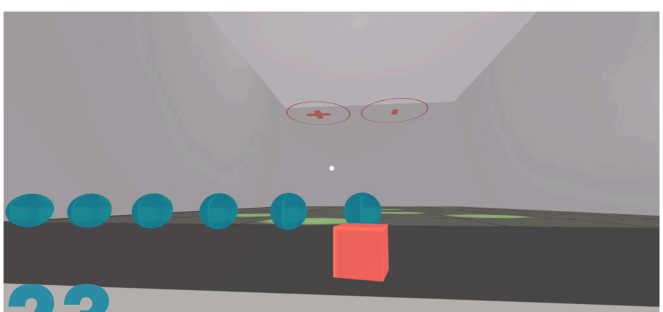
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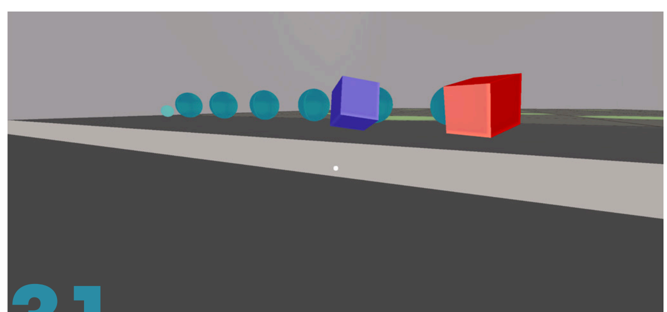
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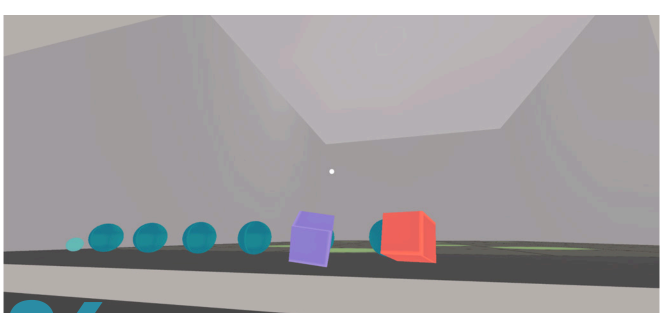
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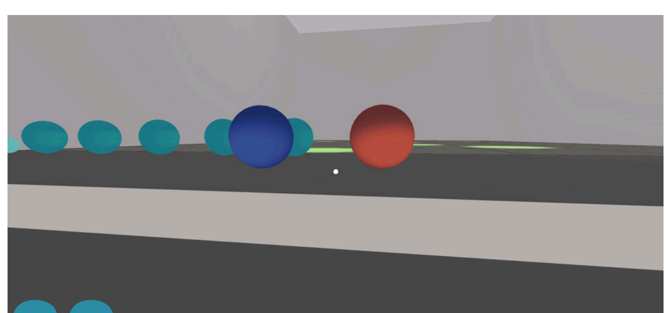
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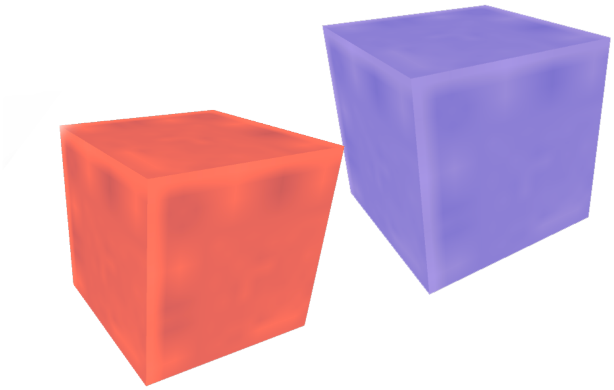
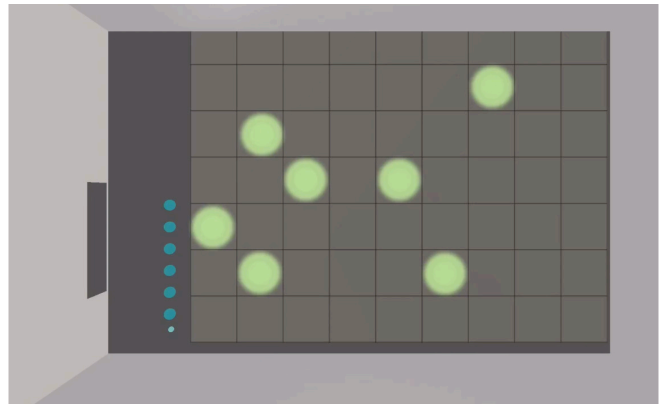
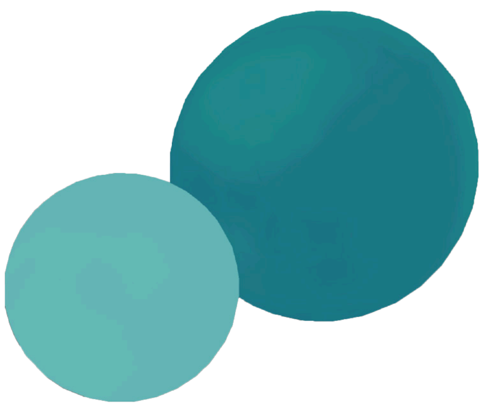
TEST SPACE

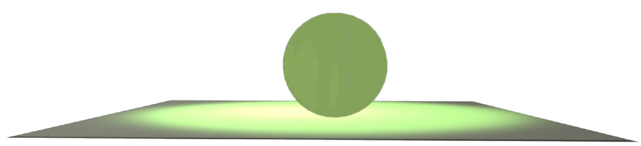




Users
In the first four of the five tests, users' embodiments are cubes. Each user is a different colored cube. In the fifth test, users' embodiments are spheres. I explain the conditions for each test in the experiment section.

Room
The room used for all five experiments is a gray room with light grey walls, dark grey floor, with a 7 x 9 gridded floor. Squares dedicated to complete the tasks and trigger the spheres to turn green are lit by a green circle. On the wall near user starting area is a plane with a mirror texture on it. This mirror gives users the opportunity to see themselves.





Objects
The room has seven objects in the space that can move but not by themselves. Biocca and Harms would classify these as non-sentient objects. Because spheres cannot be horizontal nor vertical, symmetry does not apply. The six larger cubes are harder to move and are a darker hue of bluish-green. The smaller ball is a lighter blue and is much easier to move. Once a user pushes this ball it will continue to move in the direction pushed. This makes getting it into the proper square more difficult.

Objective
The objective of the space is for all the users to push the blue spheres into the green-lit squares. When the user pushes a sphere into the appropriate square, the sphere changes from blue to green. If the user pushes the sphere out of the square it turns back to blue. The light blue sphere changes in exactly one of the green-lit squares. No other blue square will light up in the little sphere's square. This is the puzzle mechanic to the environment. Users must work together and think critically to figure out the puzzle.

USER TESTING

METHODS

For my test, I engaged with five different groups of students, a total of 69 participants. I picked five different design classes with sizes ranging from 9 to 30. I conducted the experiments during their class time. An average run of my test ran for 20 – 30 minutes. I conducted the test in an area near the class in session but removed and isolated. I chose this to cut down on noise and possible distractions. I also wanted the delay between each group of students to be as minimal as possible.

I conducted the test with three black I AM Cardboard headsets. These were purchased for their durability, ease of cleaning, and ability to accommodate people who wear glasses. From personal experience, the second version of Google Cardboard works better for button input which is also why I chose these headsets.

I used three RED 16gb iPod Touches, 6th generation. These were the same set of iPod touches used for all five of my experiments. These were the only available device that I could check-out from my department of which I was able to have three. While the screen size might have affected my overall results, it stayed constant from test to test.

When I entered the class, I explained the procedure to everyone. I told them I was doing a VR test for my thesis. I would take people in groups of three if they were willing to participate. The test would take ten minutes to run in VR followed by a short 5-minute questionnaire and 5-minute discussion. I asked them for the sake of keeping my conditions the same test to test that they didn't talk about what they experienced with their other classmates until everyone has gone. As far as I am aware, there was no test to test contamination. After I explained the general flow of my test, I started on one side of the classroom and moved my way of through group by group.

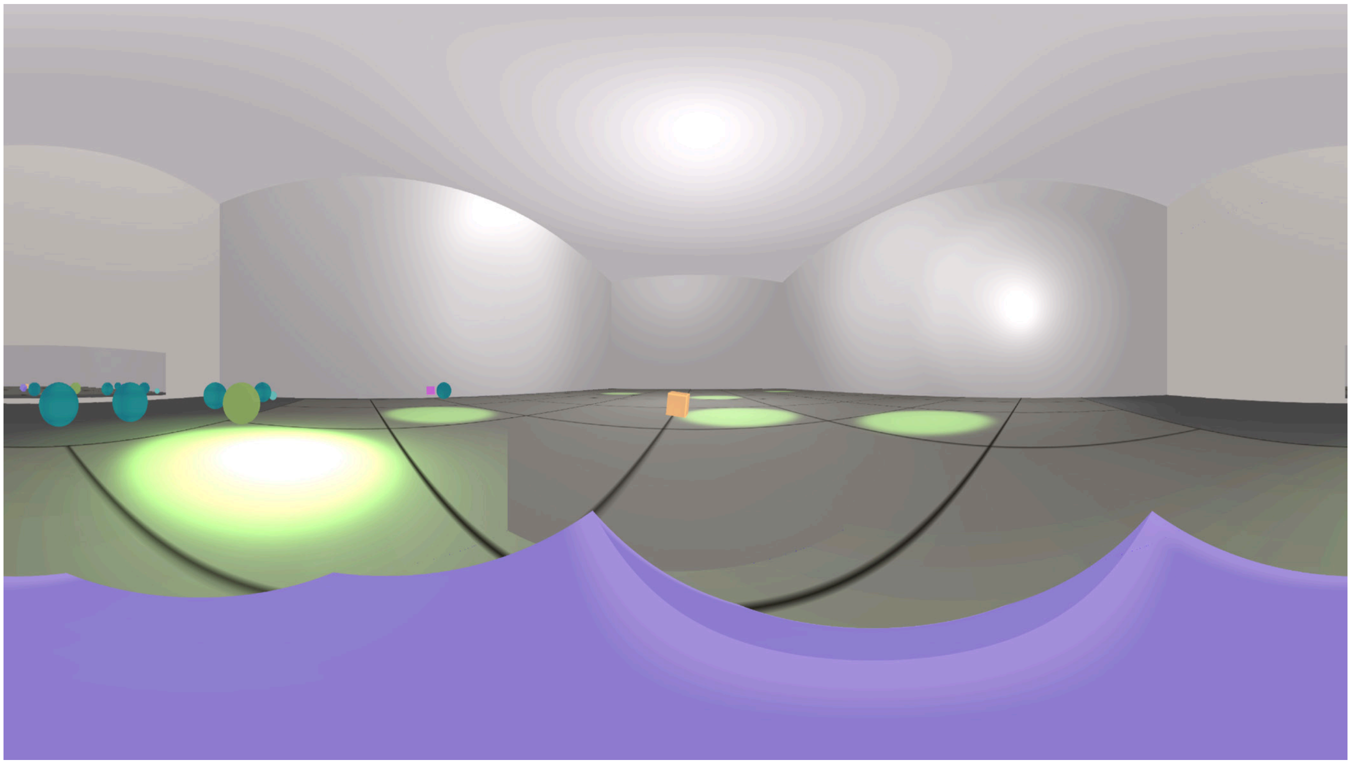
Prior to getting the group out, I checked the area I planned to test in. Did it have chairs that participants could rotate in. I did this with a stool for three tests and rolling chairs for the other two. I insured that there was at least six feet of distance between each chair. This was because during preliminary tests, if the users were too close together, the sound of them pushing the buttons conflicted with the visual representations of the users. I wanted to ensure that this did not conflict in my actual tests. On a nearby table I set up an iPad Air 2 connected to a 2010 MacBook Pro. I used QuickTime's screen grab to record the participants in the VR environment.

At the start of each group's test, I asked who has used VR before. I explained the general idea of VR and how it tracks your head movements. I then moved into the VR headsets I was using for my tests and how the iPod touches were the display screens. I explained how to move in the space, through the button input on the top of the VR headset. I showed them how to adjust the iPod touch in the headset if they were seeing double vision. I asked that during the test, they tried to ask questions or vocalize their reactions as a way not to disturb the other participants. In early tests, I found that people would talk to each other if I did not give this instruction. Since audio and verbal communication was outside the scope of this investigation, I added that constraint on the test. I reminded them that the test would run for ten minutes. I had everyone start together and everyone end together. I did not explain that the other users were in the same VR environment with them nor that there was a task for them to complete in the environment. This was because I wanted to see how the visual qualities of the users informed the participants of each other's presence. Once the users established presence, could they determine a way to non-verbally communicate with each other to push the spheres in the time limit. After the general explanation, I asked them to take a seat and I brought them the headsets with the scene pre-loaded and ready to go. I started recording the scene from the iPad view before I gave the headsets to participants to ensure that I was recording the initial moments of users looking around.

During the ten minutes, I watched the participants in the 3D environments. I looked to see if there was any glitch in the program. Around the 2- minute remaining mark, I made sure that I placed three iPad Air 2s next to each participant with the questionnaire pre-loaded. See the Appendix for the questions I asked.

At ten minutes, I asked them to stop. I went around and collected all the headsets. I asked them to not talk about their experience with the other participants yet. I directed them towards the questionnaire next to them. During this time, I reset the VR environment and recharged the iPod Touches to get ready for the next group. I saved the video from the iPad locally on my computer and reset the scene on there as well.

As the participants finished the questionnaire, I collected the iPads. Once all three finished, I conducted an informal discussion will all of them. I reiterated some of the questions from the questionnaire, like, "Did you know that you were a cube?" and "Did you know the other cubes were the other participants?" I used these questions to start the discussion about their experience in the space. This allowed people to learn who was what color, as well as vocalize some happiness or frustration they experienced during the test. I took general notes during this discussion. After they answered my questions, I explained that my study was not just about getting them into VR but about establishing social presence through a minimal form. The cube was a basic shape that I was using to see what were the limitations of that as a 3D digital representation of a user. In tests 2-5 I told them what my previous tests were and what the task was in the environment. After I answered any questions they had about the test, I thanked them for their time and I got a new group of participants. After collecting the data for each of the tests, I used Microsoft Excel to compare the resulting answers for each questionnaire. I calculated the percentages of the ones who either agreed or strongly agreed for each of the questions. In addition, for each test I determined how long it took the participants to learn that the task in the environment was pushing the blue spheres onto the green circles. For tests 4 and 5, I included the percentage of assertive and aggressive behaviors. Whenever a participant pushed the sphere, the prototype counted that as an assertive behavior. Whenever a participant moved into another participant, the prototype counted that as an aggressive behavior. It did not calculate if a participant pushed a sphere off a square that another user already set. The prototype calculated those values for each group in those tests.



TEST 1 – CUBE: COLOR VARIATION

Conditions

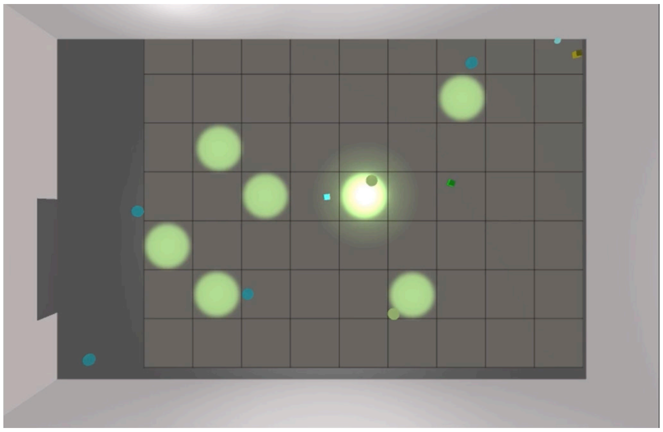
For my first test, I was creating a base condition to understand the rest of my tests. In this study, all participants were cubes, of different colors. They were either a shade of yellow, green, or blue. The order they entered the room determined this. I had the users join in the same order for each test. The person sitting closest to me entered first, followed by the middle person, followed by the one farthest away. This insured if something happened for them in the test that prevented them from using the device, I knew who to go to. The cube tracked the participants, left and right head movements. Based off my interviews with Altspace VR and Pluto VR, it was important to have level of behavioral realism projected into the space of the participants. According to Biocca and Harms, different levels of movement relay ideas of sentience to other participants. This experiment had 21 participants, 16 were female. The average age of the participants was 19.

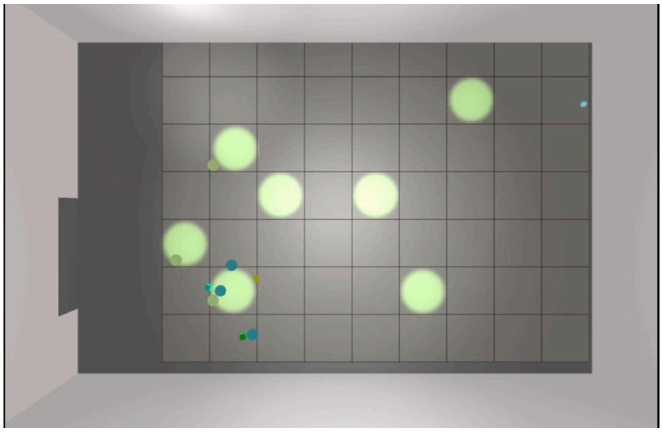
Findings

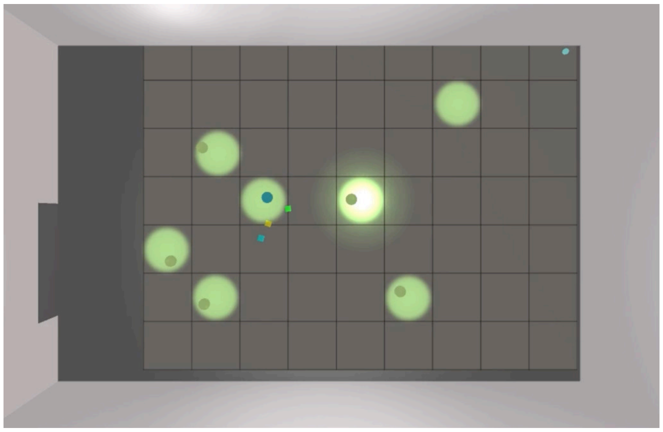
Initial questions of my questionnaire asked whether participants could distinguish what they were and what "others" were. I used others to describe the other participants or other sentient objects in the space. This is a term taken from Biocca and Harms' questionnaire. Of the 21 participants, all of them could state what they were. All of them stated that there were others in the space with them. When asked what they were, 3 of 21, 14% stated that the others were cubes and spheres. This results in either possible confusion of the question or those participants thought that the sphere were also users in the space as well.
Within the first level of social presence, co-presence, the major measure is whether participants feel that they were with another individual inside the space. On a 5-point Likert scale, 90% stated that they either Agreed (4) or Strongly Agreed (5). The other aspect is whether the participants perceived other individuals were present with them in the space. Of the 21 participants, 62% stated they either Agreed or Strongly Agreed. In similar trend participants stated they were either aware of the other individuals, 95%, and others were aware them, 57%. Overall, 86% participants felt co-present with other individuals in the space and 61% perceived to feel co-present.

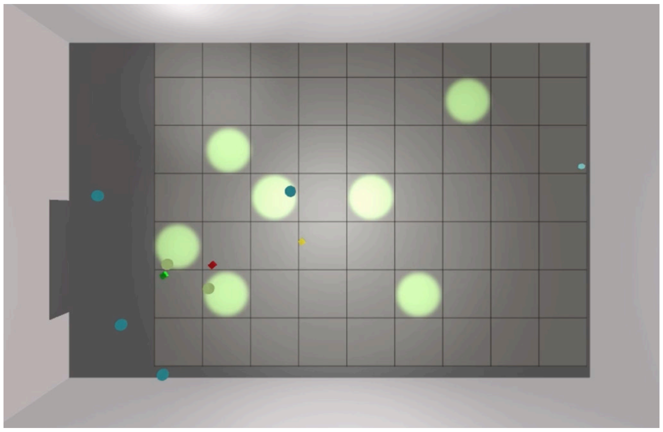
TEST 1
CUBE: COLOR VARIATION

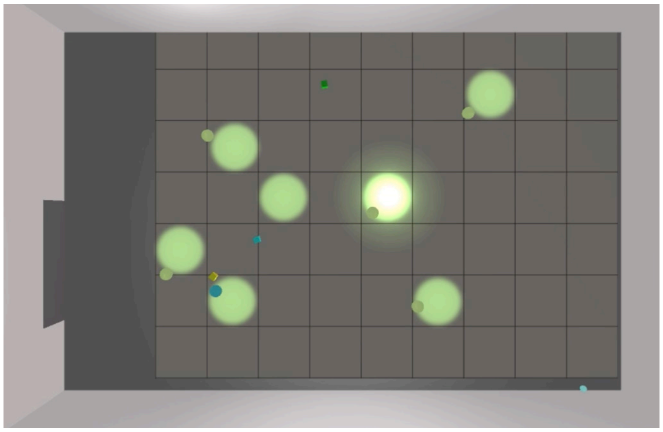
I recorded each test's VR space, using an iPad and screen record. This is the last frame of each test, as the participants stood when I called time.

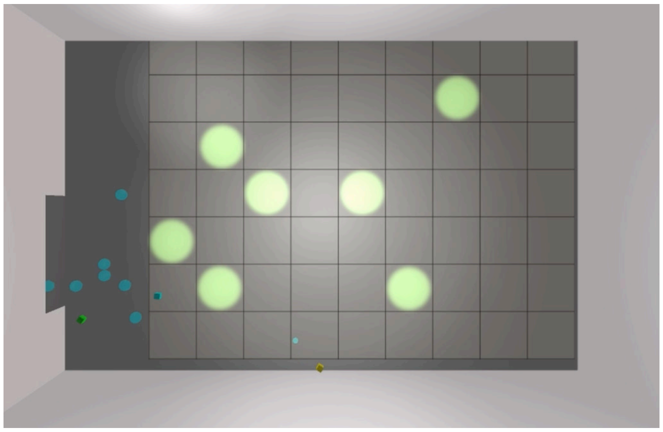


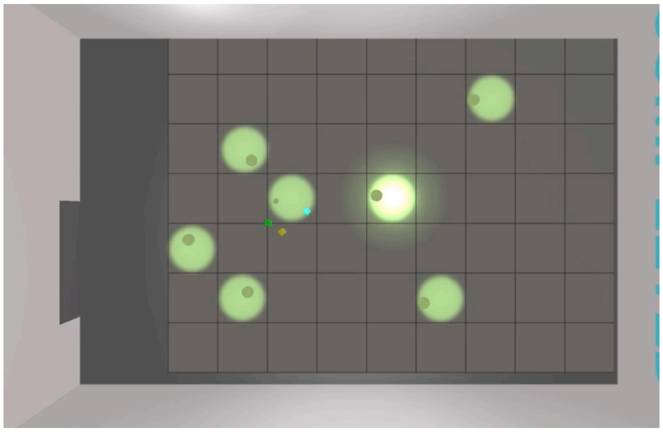












Question	Percentage that either Agreed or Strongly agreed
I often felt as if the other individual and I were in the same room together.	90%
I think the other individual often felt as if we were in the same room together.	62%
I was often aware of others in the room.	95%
Others were often aware of me in the room.	57%
I hardly noticed others in the room.	5%
The other individual didn't notice me in the room.	5%
I often felt as if we were in different places rather than together in the same room.	10%
I think the other individual often felt as if we were in different places rather than together in the same room.	14%
Overall	73%
Overall – perception of self	86%
Overall – perceived of other	73%

The second order is about establishing a link between the participant and the other individual. The first part is about establishing a psychological link, this is divided up into attentional engagement, emotional contagion and perceived comprehension. Overall, participants stated they felt and perceived more with attentional engagement, 44%, rather than the emotional contagion, 15%, and perceived comprehension, 20%. In the attentional engagement, 48% either agree or strongly agree that they paid close attention to the others. While only 40% perceived the others paid attention to them. In emotional contagion, 13% of participants agreed that other individual's moods influenced them. The questionnaire asked participants about projecting three feelings, happy, sad, and nervous. Of the them, 13% thought that their feeling influenced others, and 19% perceived the other individual's happiness influenced them.

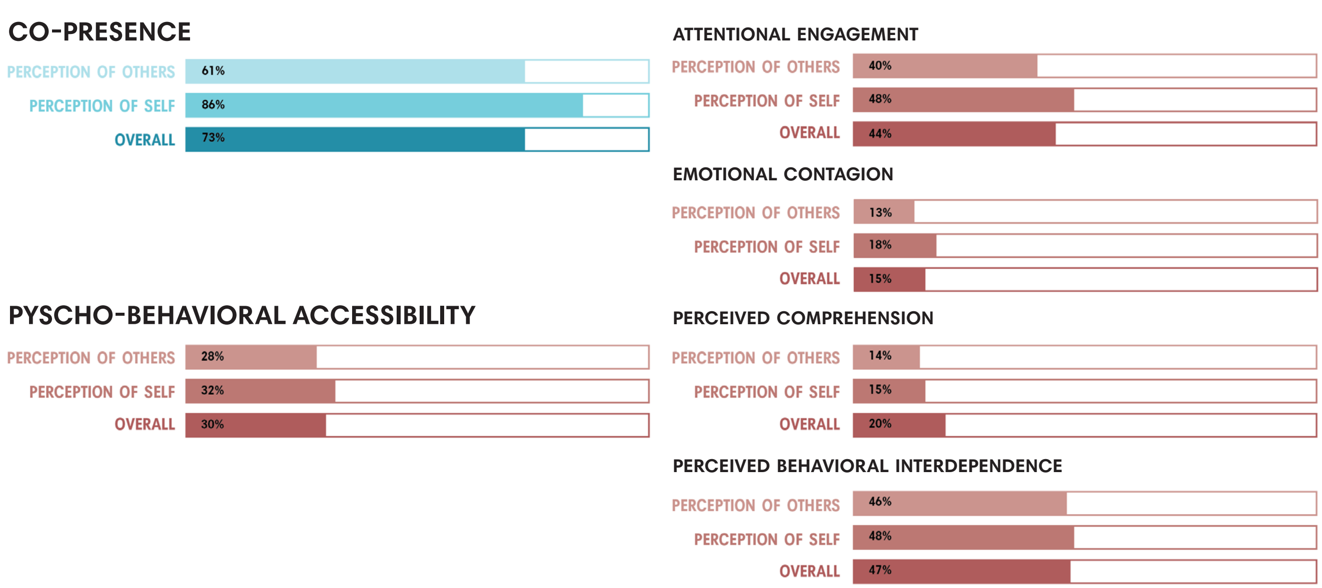
Attentional engagement	44%
Perception of self	48%
Perception of others	40%
Emotional Contagion	15%
Perception of self	18%

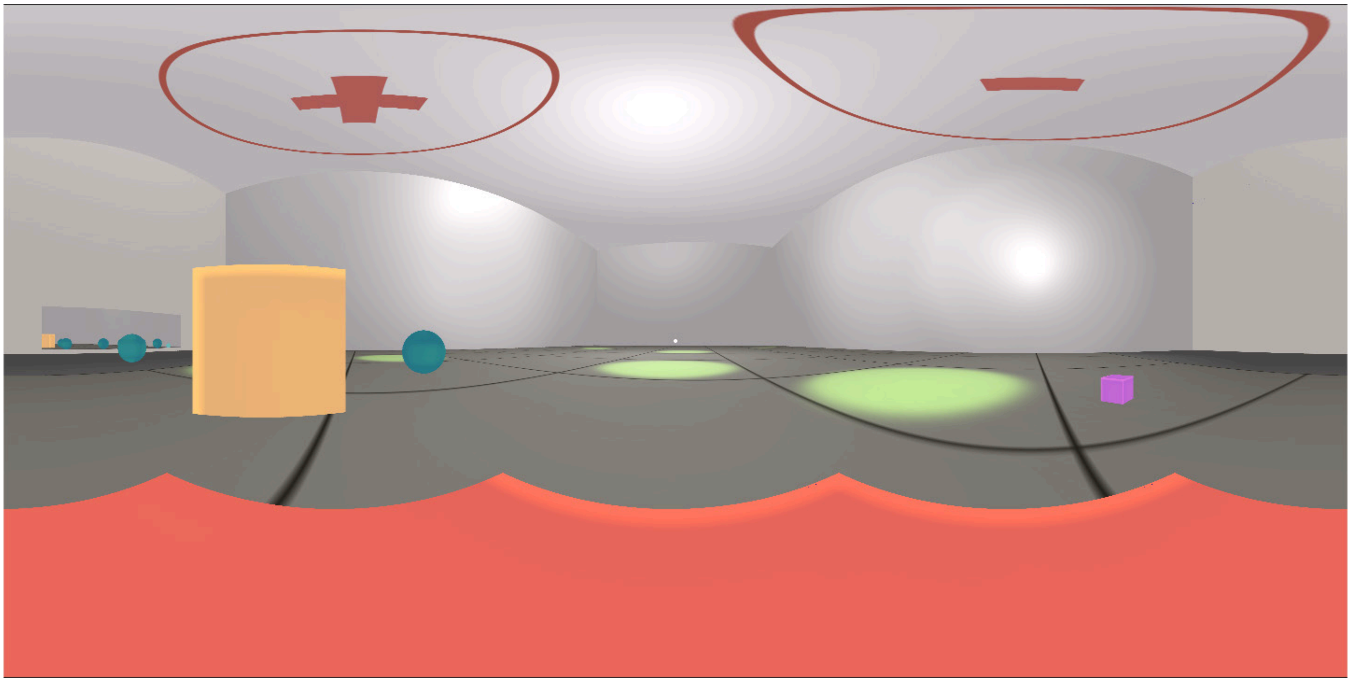
Perception of others	13%
Perceived Comprehension	20%
Perception of self	15%
Perception of others	14%
Overall	25%
Perception of self	28%
Perception of others	23%

Unlike psychological perception, 47% agreed that their actions were perceived as influencing others and others' actions influenced them. The break down for perception of one's own actions is 48% agreement and 46% for perceptions of other actions.

Perceived behavioral interdependence	47%
Perception of self	48%
Perception of others	46%

The average time it took for participants to push the blue sphere onto the sphere was 5 minutes and 17 seconds. The fastest time in this was 40 seconds. One group never figured it out during the entire 10 minutes.





TEST 2 – CUBE: SCALE VARIATION

Conditions
For my second test, I added the ability for participants to project more of their own behavior into the space. This was the ability for them to change their scale. I chose this because of the perception scale has with aggressive and timid behavior. Participants changed their scale by looking up and either clicking the '+' or '-' buttons. The plus button enlarged the participants by four times. The minus button shrunk the participants by 4 times. The buttons were a continuous scale where after pushing the plus button, to go back to the starting size, the participant needed to push the minus button. Then to shrink to the smaller size they needed to push the minus button again. I did not tell the users that they could do this. Like other aspects of the VR environment, participants discovered this out through observation and exploration. This test had 18 participants, 11 were female. The average age of the participants was 21.

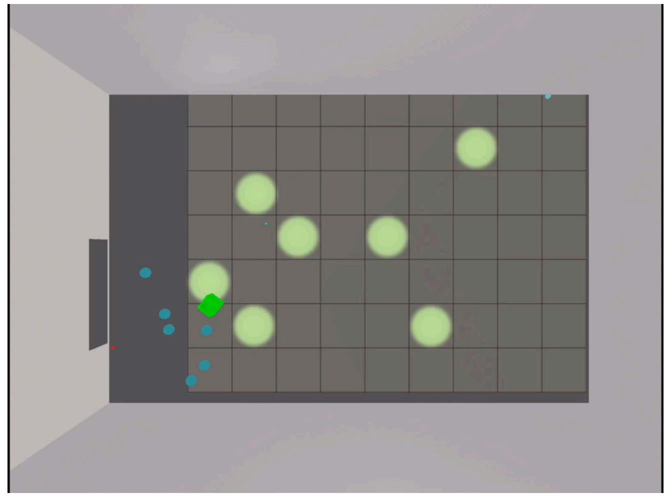
Findings
All 18 participants could establish that they were a cube. All participants answered that they were not alone in the VR space; however, 1 of the 18 thought the spheres were also being controlled by something instead of someone. Another one refers to the others as "other shapes." This could imply that they thought the spheres were being controlled as well. In this environment because the participants could change their size one participant refers to the others as "Large mean cube [and] small nice cube."

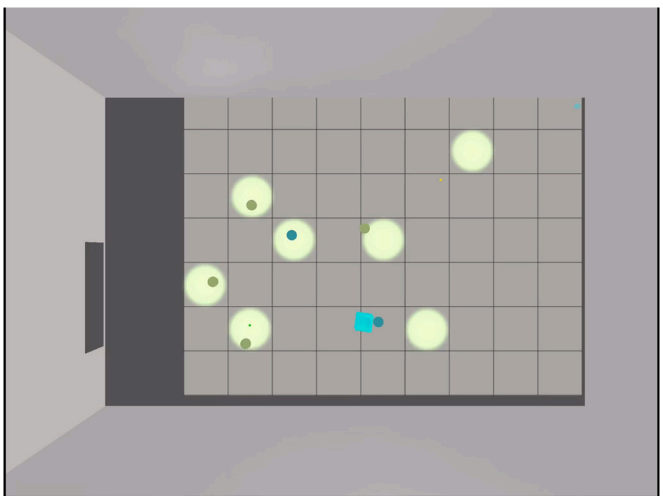
For co-presence, whether participants felt that they were with another individual inside the space, on a 5-point Likert scale, 73% stated that they either Agreed (4) or Strongly Agreed (5). The participants' perception that other individuals were present with them in the space 40% stated they either Agreed or Strongly Agreed. In similar trend participants stated they were either aware of the other individuals, 93%, and others were aware them, 47%. Of the 18 participants, 0 stated they didn't notice the others in the room and 0% thought the others perceived them in different places. Overall, 67% participants felt co-present with other individuals in the space and 44% perceived the others felt their presence.

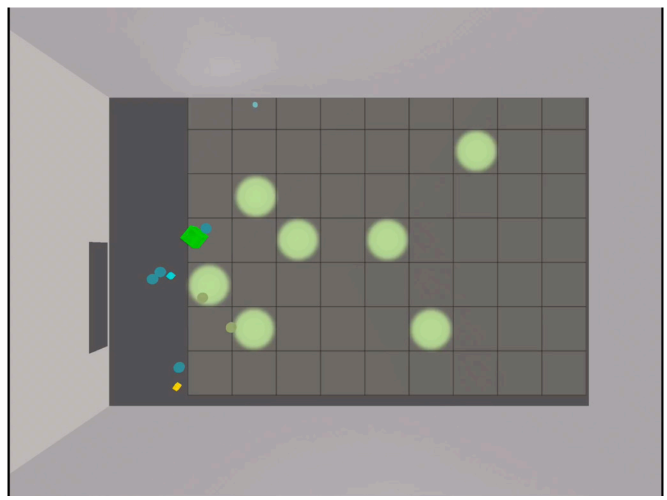
TEST 2

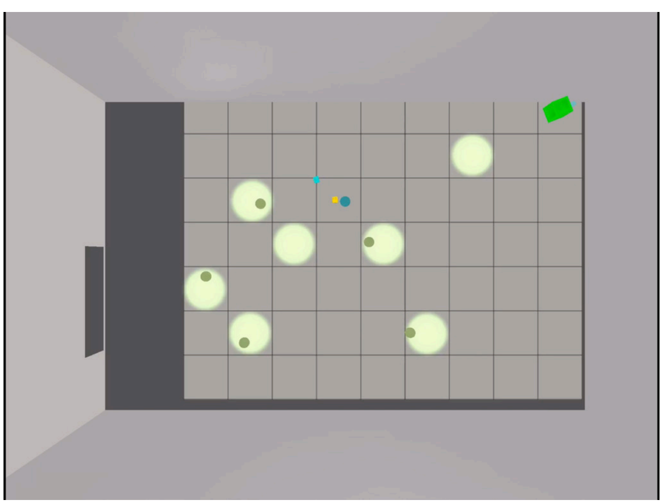
CUBE: SCALE VARIATION

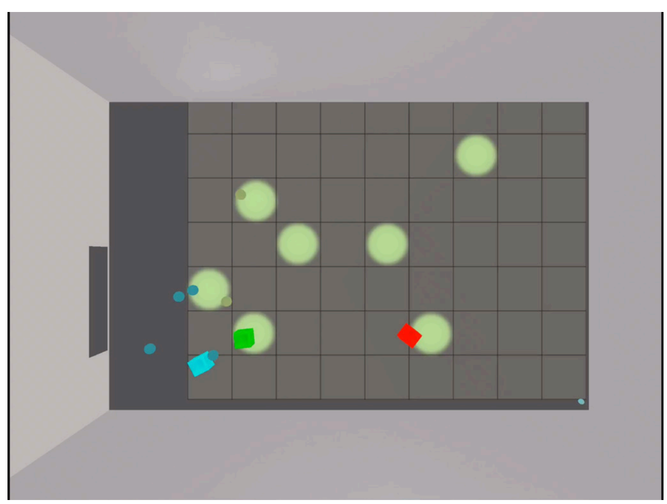
I recorded each test's VR space, using an iPad and screen record. This is the last frame of each test, as the participants stood when I called time.











Question	Percentage that either Agreed or Strongly agreed
I often felt as if the other individual and I were in the same room together.	73%
I think the other individual often felt as if we were in the same room together.	40%
I was often aware of others in the room.	93%
Others were often aware of me in the room.	47%
I hardly noticed others in the room.	0%
The other individual didn't notice me in the room.	20%
I often felt as if we were in different places rather than together in the same room.	13%
I think the other individual often felt as if we were in different places rather than together in the same room.	0%
Overall	56%
Overall – perception of self	67%
Overall – perceived of other	44%

The second order is about establishing a link between the participant and the other individual. Overall, participants stated they felt and perceived more with attentional engagement, 31%, rather than the emotional contagion, 24%, and perceived comprehension, 12%. In the attentional engagement, 39% either agree or strongly agree that they paid close attention to the others. While only 24% perceived the others paid attention to them. In emotional contagion, 24% of participants agreed that other individual's moods influenced them. The three feelings asked about in the questionnaire, 33% agreed that other's happiness within the environment influenced their own.

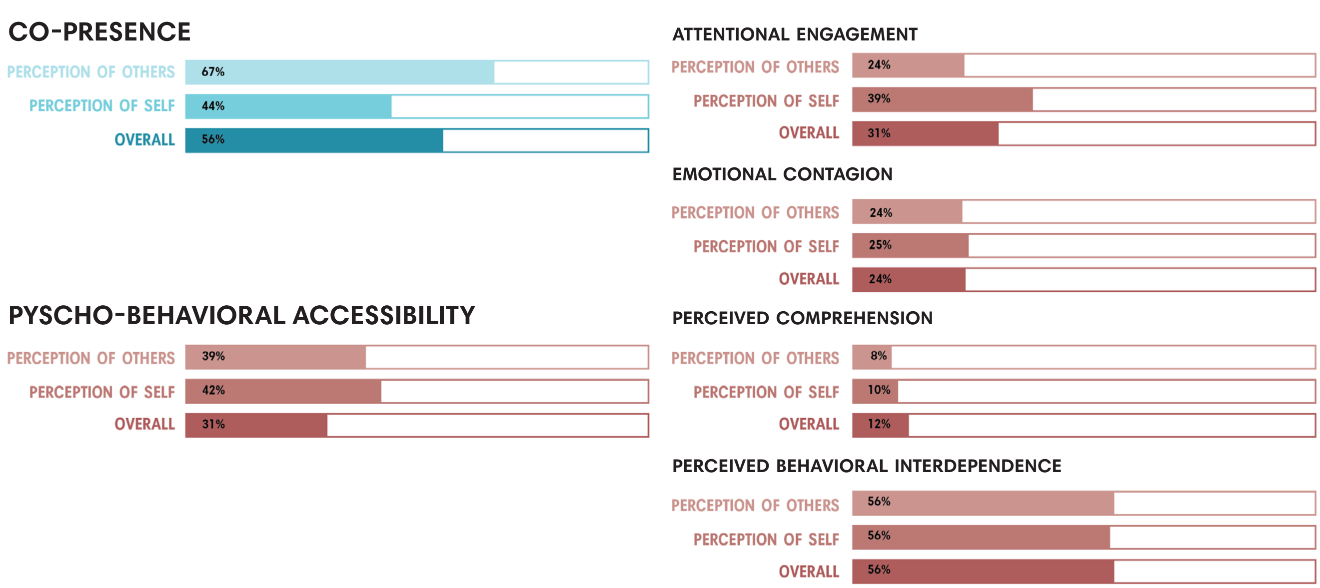
Attentional engagement	31%
Perception of self	39%
Perception of others	24%
Emotional Contagion	24%
Perception of self	25%

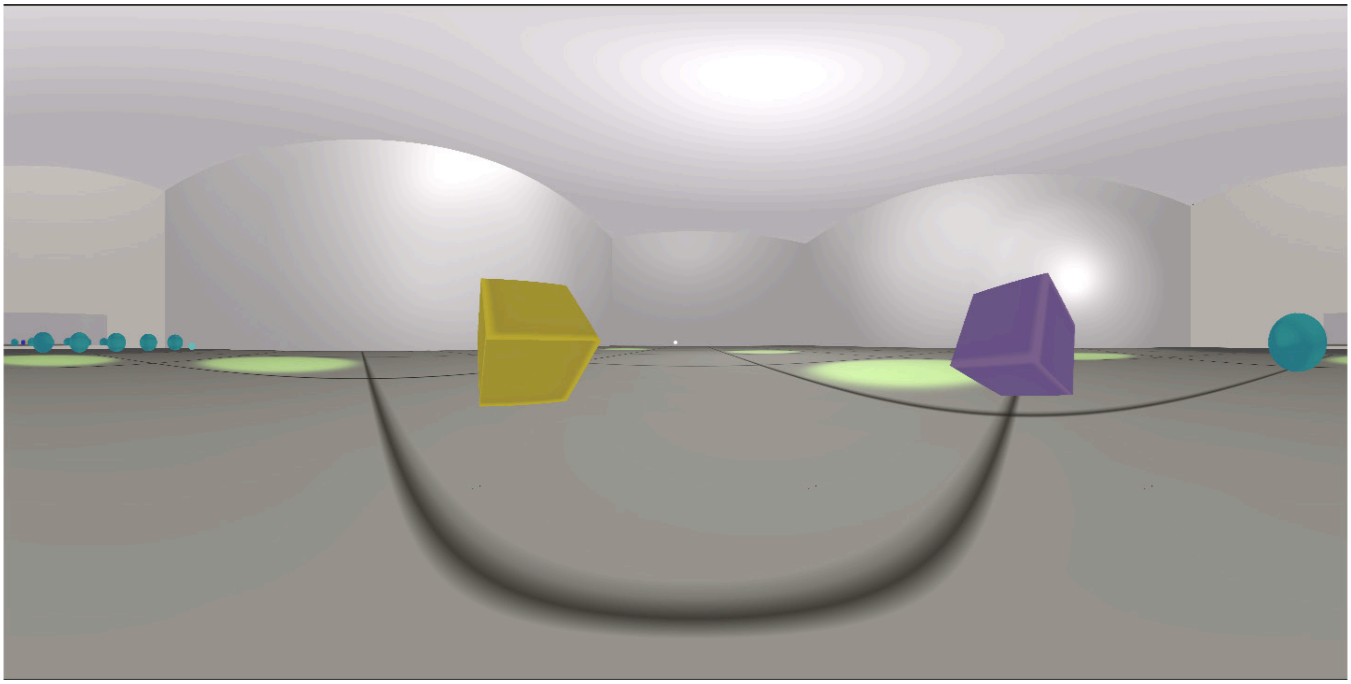
Perception of others	24%
Perceived Comprehension	12%
Perception of self	10%
Perception of others	8%
Overall	23%
Perception of self	26%
Perception of others	22%

Unlike psychological perception, 56% agreed that their actions were perceived as influencing others and others' actions influenced them. The break down for perception of one's own actions is 56% agreement and 57% for perceptions of other actions.

Perceived behavioral interdependence	56%
Perception of self	56%
Perception of others	57%

The average time it took for participants to push the blue sphere onto the sphere was 5 minutes and 50 seconds. The fastest time in this was 92 seconds. One group never figured it out during the entire 10 minutes.





TEST 3 – CUBE: HEAD-ROTATION

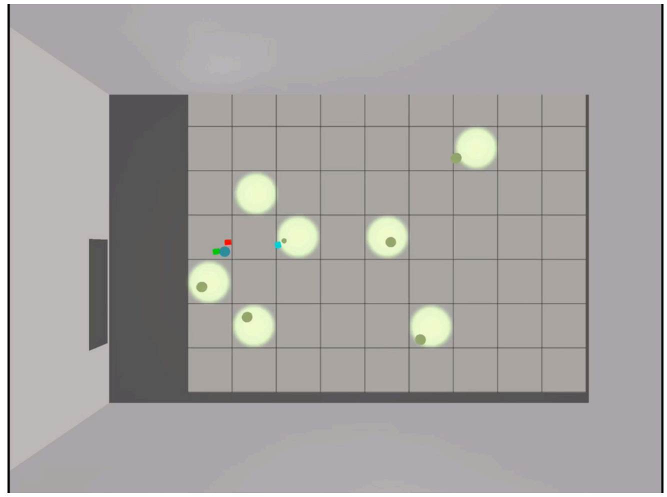
Conditions
For my third test, my condition was to determine the effect of seeing versus not seeing what you were when you looked down and,the effect of full head tracking for other participants. In test one and two, the camera was situated 2 units above the digital representation, the cube. It would feel like a user sitting on top of the thing they were controlling. For this test, the cube and camera were joined, sharing the same space. When the users looked down they would no longer see anything. Given the effect of the mirror on other tests, it did not seem to be a big deal. In lifting the cube up, off the ground plane, I could allow for full head tracking. As previously stated in the test variation section, I had issues with that up until this test. It was still three participants, represented as cubes, trying to push the spheres for ten minutes. In this test, there were nine participants. There were four males and five females. The average age was 25.

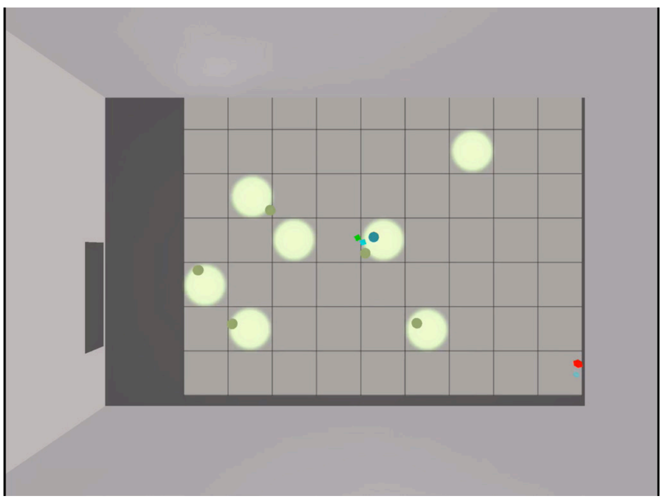
Findings
All eight participants could establish that they were a cube. All participants answered that they were not alone in the VR space and that the cubes were the sentient objects and the spheres were the non-sentient. One thought a computer controlled the other cubes. Since there was nothing to look down, all participants took cues from the mirror to establish that they were a cube. Two listed that the other cubes helped in addition to the mirror.

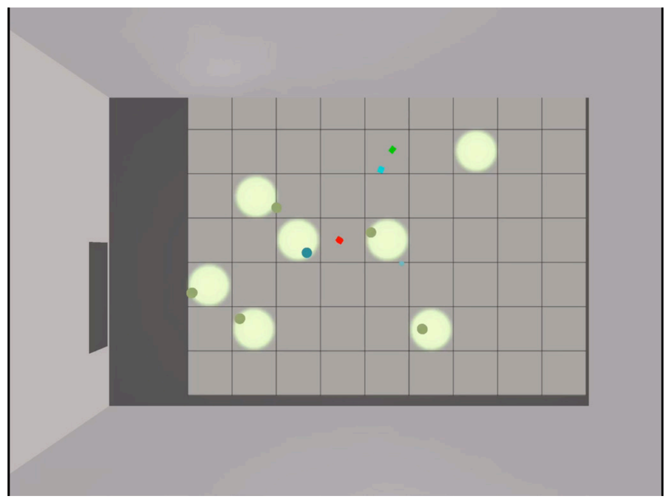
For initial values of co-presence, 78% stated that they either Agreed (4) or Strongly Agreed (5). The participants' perception that other individuals were present with them in the space 44% stated they either Agreed or Strongly Agreed. In similar trend participants stated they were either aware of the other individuals, 67%, and others were aware them, 56%. Of the nine participants, 0 stated they didn't notice the others in the room and 0% agreed that the others didn't notice them. Overall, 75% participants felt co-present with other individuals in the space and 50% perceived the others felt their presence.

TEST 3
CUBE: HEAD-ROTATION

I recorded each test's VR space, using an iPad and screen record. This is the last frame of each test, as the participants stood when I called time.







Question	Percentage that either Agreed or Strongly agreed
I often felt as if the other individual and I were in the same room together.	78%
I think the other individual often felt as if we were in the same room together.	44%
I was often aware of others in the room.	67%
Others were often aware of me in the room.	56%
I hardly noticed others in the room.	0%
The other individual didn't notice me in the room.	0%
I often felt as if we were in different places rather than together in the same room.	11%
I think the other individual often felt as if we were in different places rather than together in the same room.	0%
Overall	63%
Overall – perception of self	75%
Overall – perceived of other	50%

In the psychological involvement side of the second order, participants stated they felt and perceived more with attentional engagement, 35%, rather than the emotional contagion and perceived comprehension, 17% each. In the attentional engagement, 37% either agree or strongly agree that they paid close attention to the others. While only 33% perceived the others paid attention to them. In emotional contagion, 14% of participants agreed that other individual's moods influenced them. The three feelings asked about in the questionnaire, 22% agreed that other's happiness within the environment influenced their own. This is the only feeling that participants stated others influenced them and they influenced others. Overall, 23% of participants felt their emotional state influenced others, while 21% agreed others emotional state influenced them.

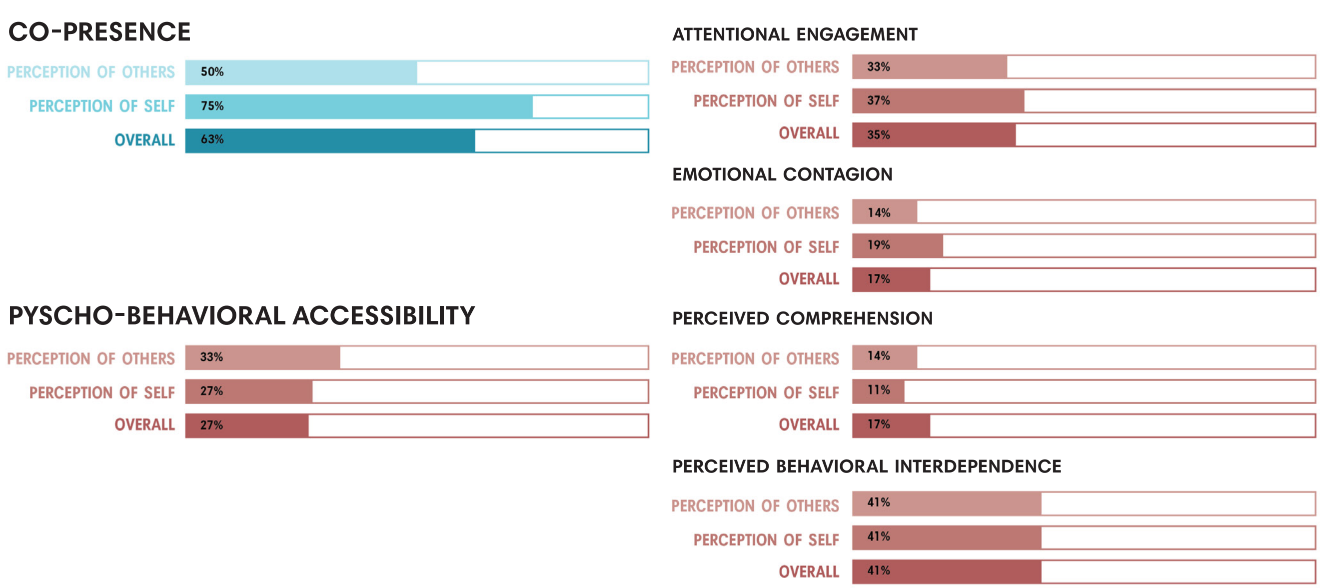
Attentional engagement	35%
Perception of self	37%
Perception of others	33%
Emotional Contagion	17%
Perception of self	19%
Perception of others	14%

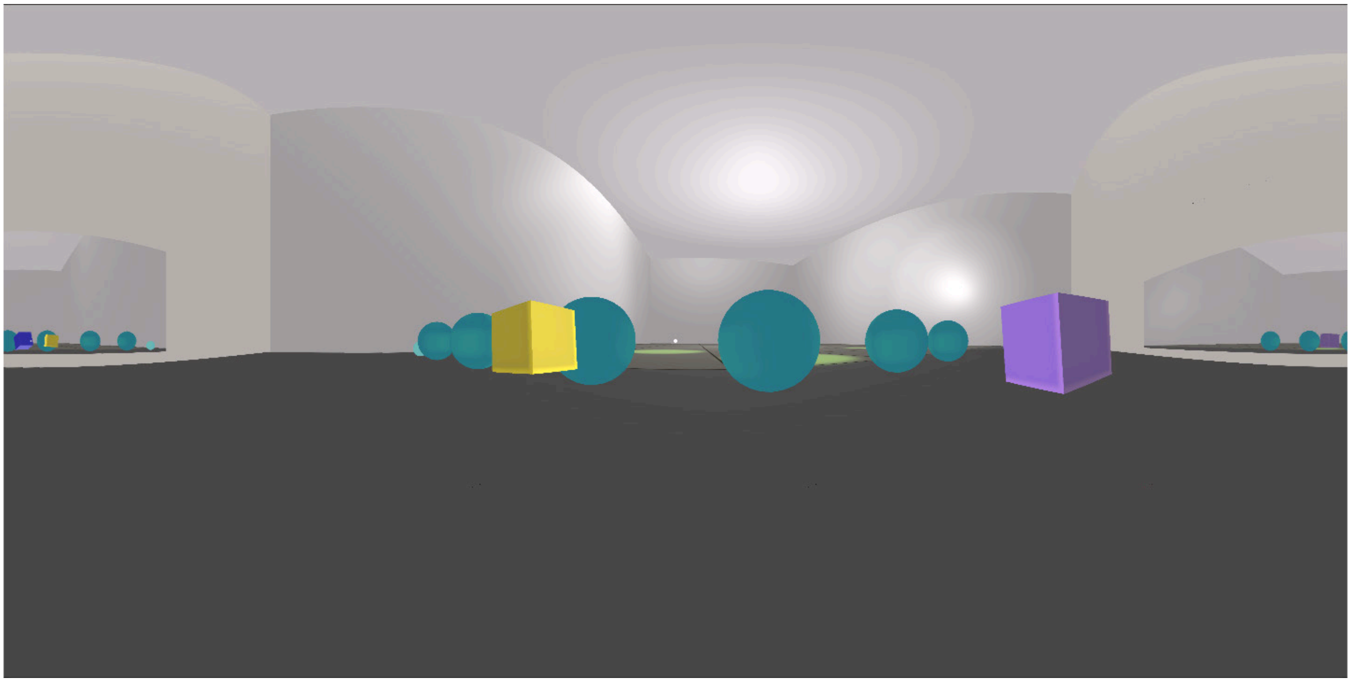
Perceived Comprehension	17%
Perception of self	11%
Perception of others	14%
Overall	22%
Perception of self	23%
Perception of others	21%

For behavioral interdependence, 41% agreed that they perceived their actions influenced others and others' actions influenced them. The perception of self and others were the same.

Perceived behavioral interdependence	41%
Perception of self	41%
Perception of others	41%

The average time it took for participants to push the blue sphere onto the sphere was 3 minutes. The fastest time in this was 138 seconds.





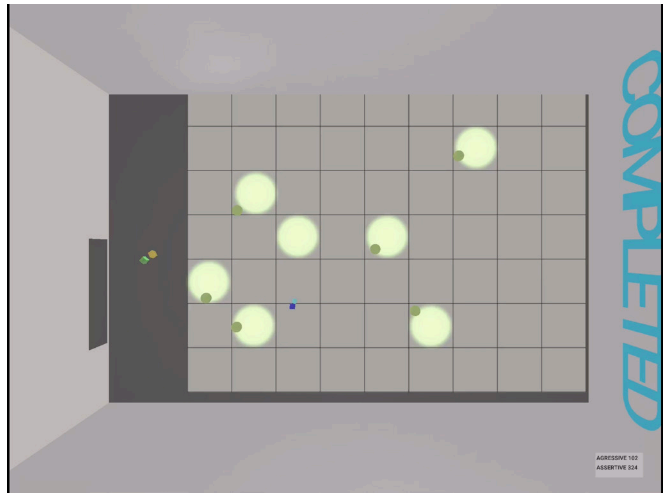
TEST 4 – CUBE: HEAD-ROTATION + LIGHTER FACE

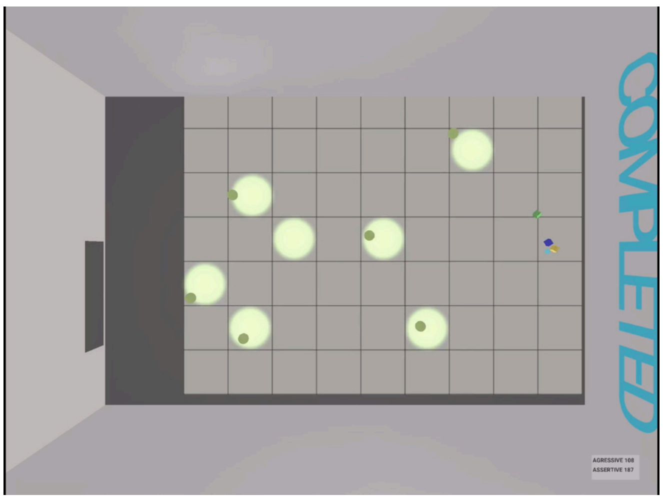
Conditions
For my fourth test, my condition was the same as the third but the front face of the cube was a lighter color. The idea for this was that a user could look at the cube and know if it was looking at them or away. The application assigned this dynamically so each user still was given a distinct color. The front face was 20% lighter. In this test there were 12 participants, 9 males. The average age of the participants was 20.

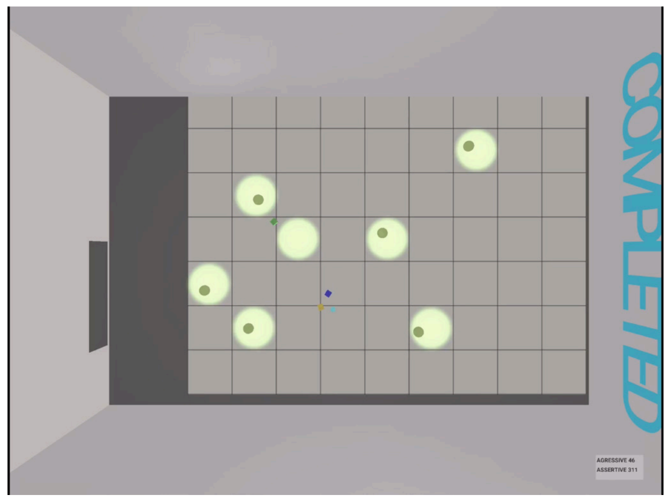
Findings
All 12 of the participants could distinguish that they were cubes of different colors. All participants could recognize that other objects were in the space that could move on their own. One of the twelve thought they were an A.I or computer automated user. As in the previous tests, the mirror was important to help establish the knowledge that the participants were cubes.
For initial values of co-presence, 83% stated that they agreed that they were with other individuals. The participants' perception that other individuals were present with them in the space 75% stated they agreed. In similar trend participants stated they were either aware of the other individuals, 92%, and others were aware them, 67%. Of the twelve participants, one participant stated they didn't notice the others in the room and two agreed that the others didn't notice them. Overall, 90% participants felt co-present with other individuals in the space and 75% perceived the others felt their presence.

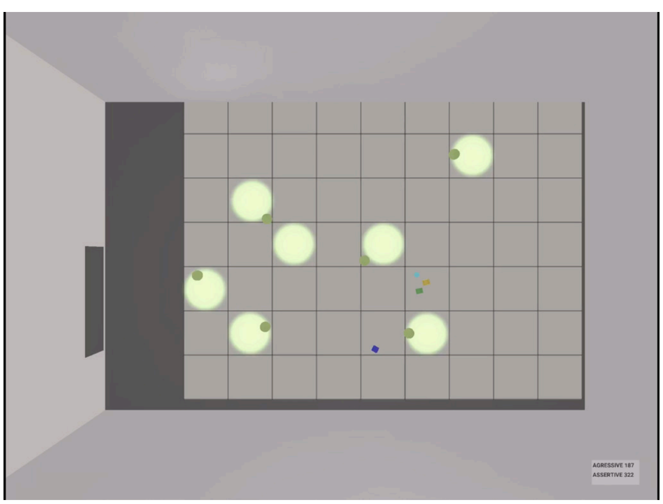
TEST 4
CUBE: HEAD-ROTATION + LIGHTER FACE

I recorded each test's VR space, using an iPad and screen record. This is the last frame of each test, as the participants stood when I called time.









Question	Percentage that either Agreed or Strongly agreed
I often felt as if the other individual and I were in the same room together.	83%
I think the other individual often felt as if we were in the same room together.	75%
I was often aware of others in the room.	92%
Others were often aware of me in the room.	67%
I hardly noticed others in the room.	8%
The other individual didn't notice me in the room.	17%
I often felt as if we were in different places rather than together in the same room.	0%
I think the other individual often felt as if we were in different places rather than together in the same room.	8%
Overall	82%
Overall – perception of self	90%
Overall – perceived of other	75%

In the psychological involvement side of the second order, participants stated they felt and perceived more with attentional engagement, 36%, rather than the emotional contagion, 20%, and perceived comprehension, 15%. In the attentional engagement, 39% either agree or strongly agree that they paid close attention to the others. While only 33% perceived the others paid attention to them. In emotional contagion, 17% of participants agreed that other individual’s moods influenced them. Of the three feelings asked about in the questionnaire, 17% agreed that other’s happiness, sadness, and nervousness within the environment influenced their own. Overall, 26% of participants felt their emotional state influenced others, while 21% agreed others emotional state influenced them.

Attentional engagement	36%
Perception of self	39%
Perception of others	33%
Emotional Contagion	20%
Perception of self	23%
Perception of others	17%
Perceived Comprehension	15%

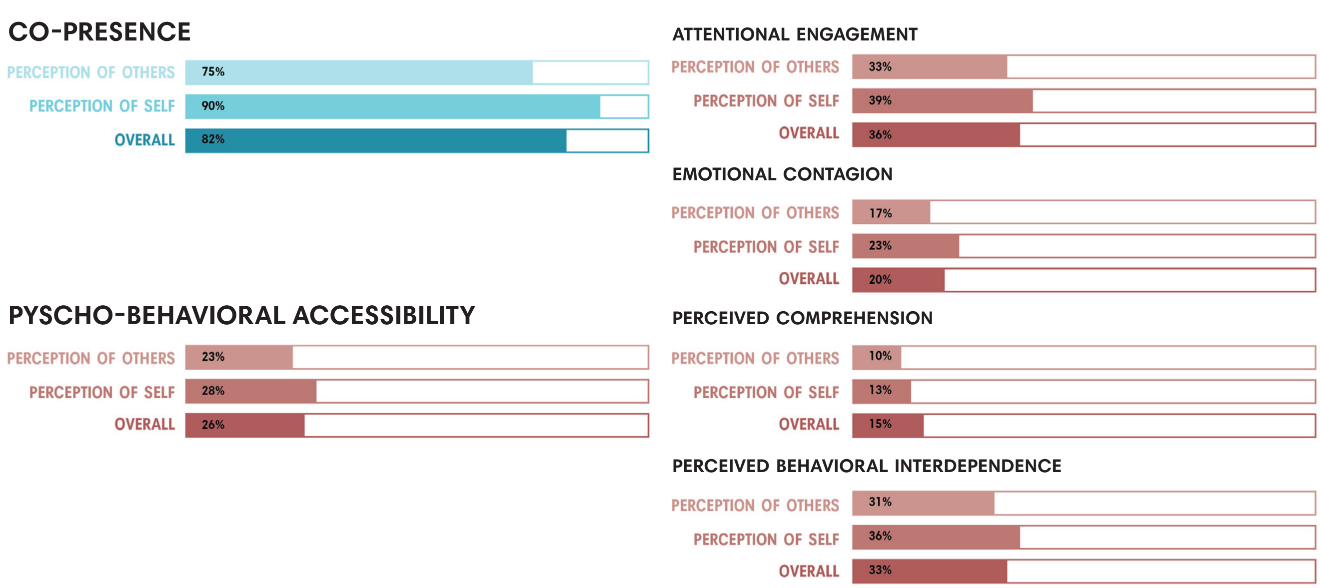
Perception of self	13%
Perception of others	10%
Overall	23%
Perception of self	26%
Perception of others	21%

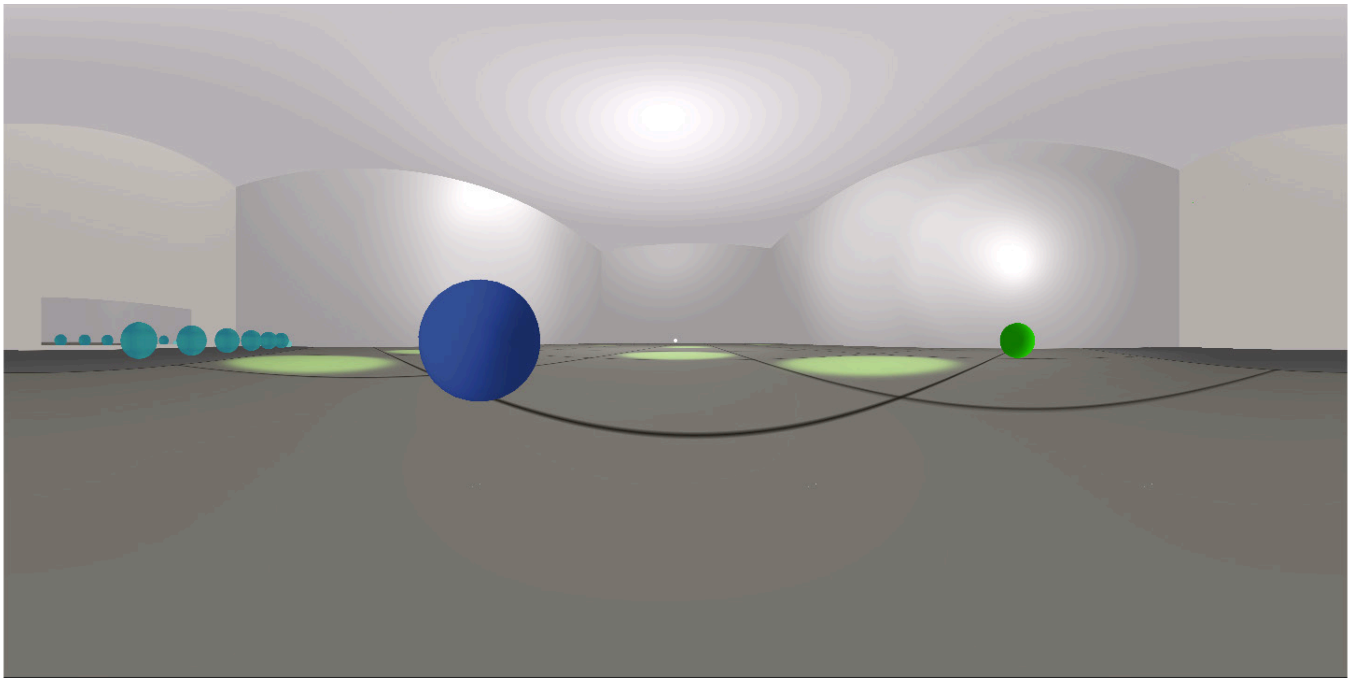
For behavioral interdependence, 33% agreed that they perceived their actions influenced others and others' actions influenced them. The participants' responses break down into 36% agree that their behavior was influencing others and 31% agreed other participants' behavior affected them.

Perceived behavioral interdependence	33%
Perception of self	36%
Perception of others	31%

The prototype calculated 72% of all behaviors were to be assertive behaviors. One group scored almost 50/50 aggressive and assertive. All groups scored more assertive than aggressive.

The average time it took for participants to push the blue sphere onto the sphere was 2 minutes and 17 seconds. The fastest time in this was 60 seconds. Three of four of the groups completed the task in under 10 minutes.





TEST 5 – SPHERE: HEAD ROTATION + LIGHTER FACE

Conditions

For my fifth test, my condition was whether the shape itself had any factor in establishing presence. When all the participants and the objects in the space are the same shape, does this make it more confusing for participants or is there enough behavior from other participants projected into the space that presence is still established? In a sphere where there is no "face" can a texture give a perception of a face to inform participants where they are looking? These are the conditions I was observing in this test. There were 9 participants, 8 of which were female. The average age was 24.

Findings

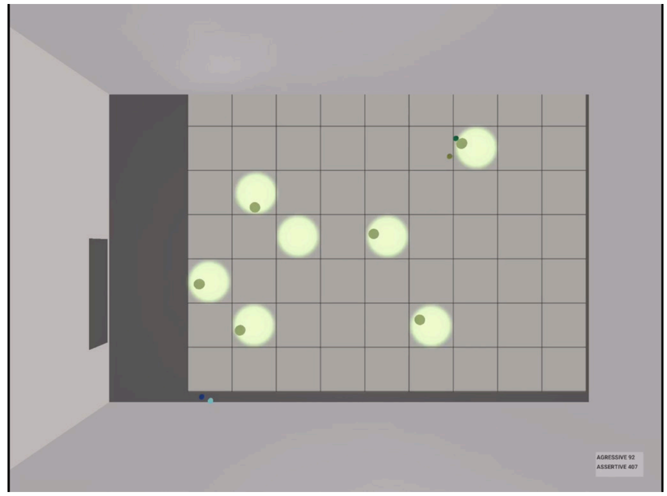
All nine of the participants could distinguish that they were cubes of different colors. All participants could recognize that other objects were in the space that could move on their own. Five of the nine thought they were an A.I. or computer automated user. From this answer, it appears that there was some confusion of the shapes, or that the spheres did not embody enough of the users' behavior for them to feel more "natural" and less "robotic."

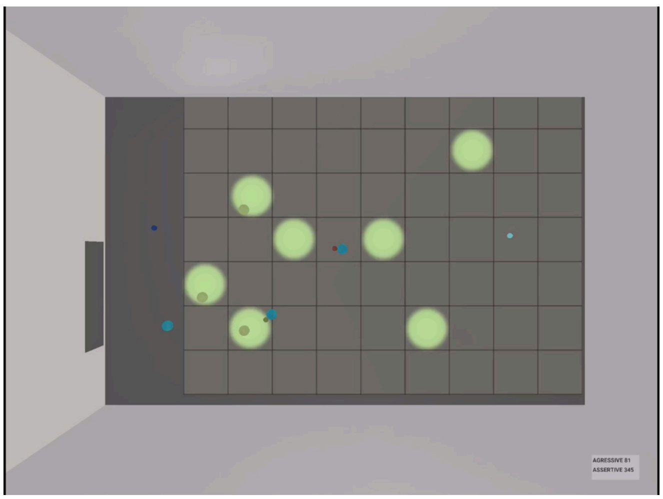
For initial values of co-presence, 78% stated that they agreed that they were with other individuals. Regarding the participants' perception that other individuals were present with them in the space, 33% stated they agreed. Similarly to the first question, 78% were aware of the other individuals. Of the nine participants, 22% stated they didn't notice the others in the room and 33% agreed that the others didn't notice them. Overall, 72% participants felt co-present with other individuals in the space and 36% perceived the others felt their presence.

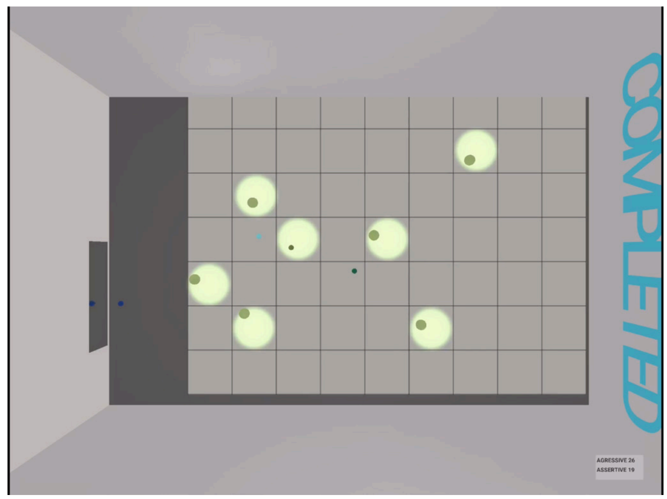
TEST 5

SPHERE: HEAD-ROTATION + LIGHTER FACE

I recorded each test's VR space, using an iPad and screen record. This is the last frame of each test, as the participants stood when I called time.







Question	Percentage that either Agreed or Strongly agreed
I often felt as if the other individual and I were in the same room together.	78%
I think the other individual often felt as if we were in the same room together.	33%
I was often aware of others in the room.	78%
Others were often aware of me in the room.	22%
I hardly noticed others in the room.	22%
The other individual didn't notice me in the room.	33%
I often felt as if we were in different places rather than together in the same room.	22%
I think the other individual often felt as if we were in different places rather than together in the same room.	22%
Overall	54%
Overall – perception of self	72%
Overall – perceived of other	36%

In the psychological involvement side of the second order, participants stated they felt and perceived more with attentional engagement, 31%, rather than the emotional contagion, 13.9%, and perceived comprehension, 20%. In the attentional engagement, 33% either agree or strongly agree that they paid close attention to the others. While only 30% perceived the others paid attention to them. In emotional contagion, 11% of participants agreed that other individual's moods influenced them. The three feelings asked about in the questionnaire, 11% agreed that other's happiness, sadness, and nervousness within the environment influenced their own. Overall, 22% of participants felt their emotional state influenced others, while 20% agreed others emotional state influenced them.

Attentional engagement	31%
Perception of self	33%
Perception of others	30%
Emotional Contagion	14%
Perception of self	17%
Perception of others	11%

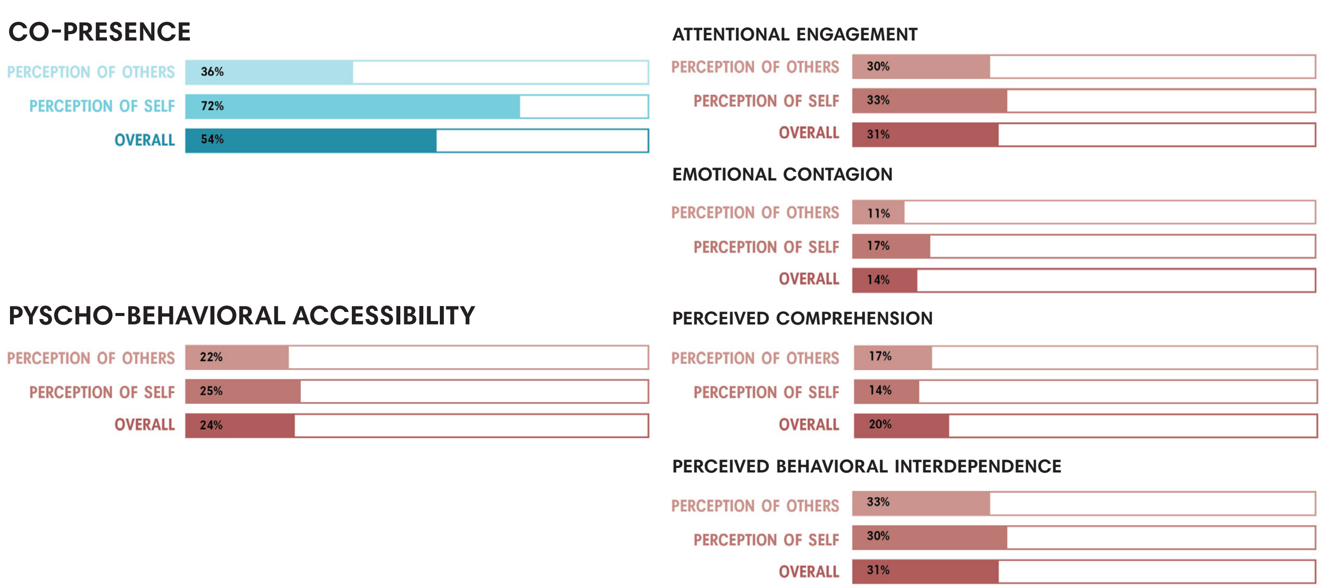
Perceived Comprehension	20%
Perception of self	14%
Perception of others	17%
Overall	21%
Perception of self	22%
Perception of others	20%

For behavioral interdependence, 31% agreed that they perceived their actions influenced others and others' actions influenced them. The participants' responses break down into 33% agree that their behavior was influencing others and 30% agreed other participants' behavior affected them.

Perceived behavioral interdependence	31%
Perception of self	33%
Perception of others	30%

The prototype calculated 79% of all behaviors were to be assertive behaviors. One group had 92 aggressive interactions and 407 assertive ones. This makes for an almost 1:4 ratio.

The average time it took for participants to push the blue sphere onto the sphere was 4 minutes and 14 seconds. The fastest time in this was 45 seconds. One of four of the groups completed the task in under 10 minutes.



DISCUSSION

The five tests built off each other. Because of this, it is interesting to see which design decisions seemed to succeed over others. Due to lack of participants for each test, I will discuss these with that in mind.

For all 5 of the tests, I asked three participants to participate per group. This was to account for one user potentially being more a passive observer and not fully participating in the environment. I did preliminary tests with just two people, and it was harder getting the connection in the environment. In one test, one user displayed deviant behavior by constantly running into the other user. This added additional movement in the space from the bump, resulted in the bumped participant getting motion sick. After the first test, three seemed to be the most appropriate number. I primed the participants by asking three participants to come at a time and having three users in the environment. Because I did not give them any additional instructions of the space, the prime felt valid.

All 69 participants discovered that they were a cube, or sphere, for test five. That was important for establishing self-presence. From the informal discussion after the test, many participants stated they used the mirror to help them figure out what they were and knowing that they were one shape helped them understand the other shapes were players, too. One thing that was also clear from the conversations that the participants' movement was important. Numerous participants across stated, "The other shapes looked confused, and I was confused so they must be like me." The language used in discussion included, "I was a cube," "Who was the yellow?" "Did I steal the ball from you?" This leads me to believe that while I did not give participants agency of their shape, or color, they were still able to embody these shapes.

All 69 participants were aware of the other shapes moving in the room. The questionnaire asked them to state what other players were in the space. Only 8.7% participants seemed confused of which of the objects were players and which were inanimate objects. From the half I asked, 7.3% thought the other moving objects were computer-animated or an A.I. participant. While I did not add this question to the questionnaire until test 3, at least 4 participants in the first two tests informally said the same thing. Test five had a greater number of people thinking this. I wonder if it was due to the possible shape confusion because both inanimate and user were the same shape. Users were floating while the other objects were all the ground to help account for that confusion, however users did not make the embodiment connection.

Test four had the highest overall first order Co-presence percentage of 82.3% for overall and 89.6% for the perception of the users influence and 75% for the perception of the others' influence on them. In this test, users floated two units off the ground plane and had full head rotation. Their front face was 20% lighter than the rest of their bodies. While in the informal conversation, users did not state that they noticed the lighter color face. I wonder if there was a subconscious reaction to noticing a front and a back to the users. The next highest overall score was first test, where players were on the ground plane, camera sat above, and tracked left-right head movement. While the connection of the results seems somewhat unclear, I think the classes I used for this test might have influenced the results.

The time it took for users to discover the objective of the task-oriented environment mirrored the results of the values of co-presence. The test with the highest co-presence was test 4 – cube: head-rotation + lighter face. This was also the fastest average time for discovering the objective. The slowest overall time was test 2 – cube: scale variation, with 5 minutes and 50 seconds. As the values of co-presence rose, the amount of time it took for this discovery also quickened.

The second order, Pyscho-Behavioral Interaction, is divided into Perceived Psychological Engagement and Behavioral Interdependence. The Perceived Psychological Engagement asked questions related to participants' awareness of the other individuals, the projection and influence of emotions, and clarity of everyone's intentions. In all five of the tests, participants rated this part lower than the rest. Perceived attentional engagement rated the highest of the three. I think this because this was a visual understanding. It did not ask for additional input of the participants, other than were they actively aware or actively ignored the other. The other subsections, Perceived Emotional Contagion and Perceived Comprehension, asks for participants to project and be influence by more. This is where the tests need improvement. Of the five, the second test had the highest emotional contagion score, 24.3%. This test participants grew and shrunk in size from pushing a button above them. The open-ended responses reflect the higher level of influence from the comments, like "Large mean cube [and] small nice cube." Perceived comprehension was lower than Perceived Emotional Contagion. This could be because participants did not necessarily get confirmation of other users' intent. Based off discussion and observation, the states were passively watching, competing and corroborating. These states parallel with the three types of social behavioral interactions: passive, aggressive, and assertive. While these three states are observable, the perception of their influence on the participants seemed to fall short.

The second part of the second order is Perceived Behavioral Interdependence. Overall this part scored much higher than Perceived Psychological Engagement. Except for test 4 and 5, people reported 40% or greater for both perception of how they were influenced and how they influenced others. Because the environment allowed for little representation in the way of psychological states, users needed to rely heavily on behavioral representation to understand themselves, others, and the environment. Bailenson et al. stated that behavioral realism is more important than photo realism. In this environment, users could relay on abstracted forms of behavioral realism to connect with the users and establish co-presence

CONCLUSION

Embodiments are a way to represent users in a space. Users can utilize embodiments to interface actively with digital reality. In doing so, they project attributes of themselves into the environment. The strictness of the environment limits the level of user engagement. When users can be together with others in a VR environment, it opens the door to a more robust and dynamic environment in which users naturally shift towards social interactions. In an abstracted environment with primitive shapes, the robustness of social interactions is limited. From my observation, the interactions still fall into typical behavior of passive, assertive, and aggressive. Most participants in the tests took the first minute to look around the environment and understand what was around them. Confused participants at times tended to passively observe what the other individuals were doing. With further study, I could determine what would help users when they first enter the space to lower confusion. In this investigation, all users started with 2 units of each other. These units separate from the balls that they could push around in the space. Would assigning a designated "spawn" area help users make the connection that everyone starting here was just like them? Other applications I looked at, like Recroom VR and Altspace VR, use staging areas to help users become accustomed to the space. As participants felt more comfortable with the task they tended to assert their intentions by looking at themselves in the mirror or pushing the balls into the square. While looking at the mirror was not a cooperative action, it was an assertive action. For users to explore the space they rammed into each other in an aggressive action. As discussed, of the interactions participants expressed in test 4 and 5, 12 – 58% of them were aggressive. In test 2 – scale variation—participants who increased their size exhibited much more aggressive tendencies. While this was before I incorporated the counter to collect that data, personal observation and comments stated from the participants confirm this. This shows that when attributes like size are different from user to user, the change influences the behavior the user expresses. Color had no apparent effect on the users except in case-by-case situations. When one participant was being more aggressive than another, others perceived them as the "evil" one. This became apparent in the after-questionnaire conversation I had with the participants. Because this was a behavior a participant decided to do in the space, which was not predetermined by the space, , I have no current way of knowing if the color, shape, texture, had a way of influencing this.

To help facilitate social interactions, users need to be able to communicate and disclose information with each other. When the representation is more realistic, people are less likely to disclose information about themselves. They become aware that their verbal and non-verbal expressions influence the listener's perception of them. The test in this study did not include audio, but giving the users the ability to see each other's full head movement in the space resulted in higher levels of self-reported co-presence and perceived behavioral interdependence. While they did not have large amounts of personal information to disclose, this could have helped users communicate they are there with each other. In the full-head tracking tests, there were higher observations of play and cooperation between participants.

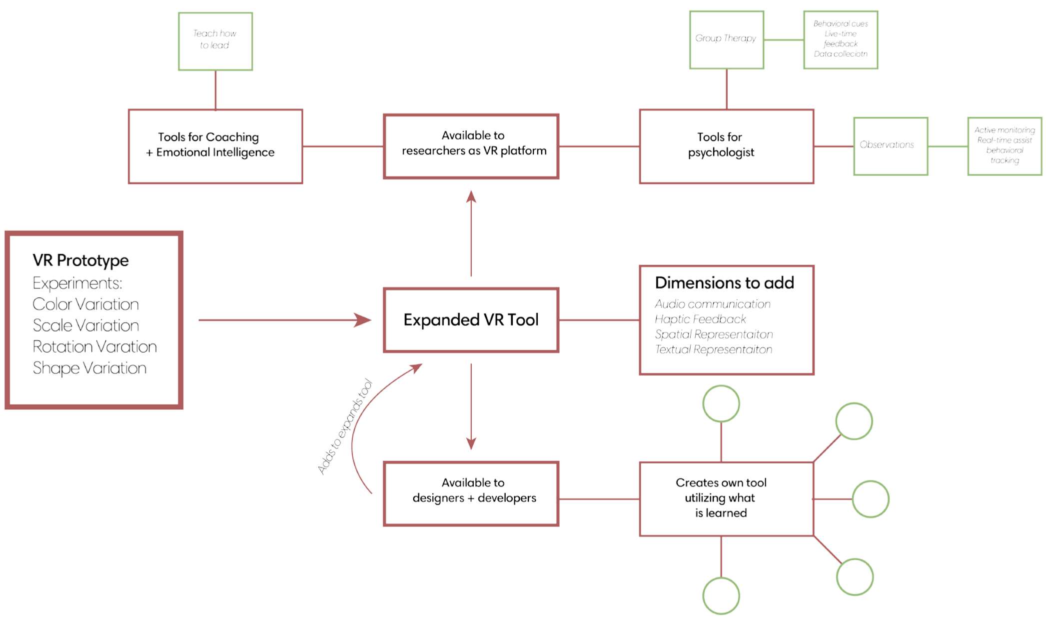
It seems giving the cube this humanistic behavior was an apt way to encourage these sorts of interactions.

Computer-mediation results in socially equal decision making, especially in task-oriented environments. It takes longer for users to make decisions together but they tend speak more freely with less inhibitions. This leads to socially equal decision making. In my non-verbal VR application, participants needed to decide whether they were going to participate in the task as cooperative helpers, deviate from the task, prevent others from completing it or just avoid it all together. There were 5 out of 22 groups to complete the task in the allotted time frame. Many more came very close. On the contrary, only two groups did not figure out at all that the balls changed colors during the test. In tests that included full-head tracking users got the point of moving the balls onto the green circles much faster. In test 4 – full head tracing + lighter face—users had an average time of 2 minutes and 17 seconds to make this discovery. The fastest group was 60 seconds. While the fastest group for all the tests was in test 1 – different colors—the rest of test 1 took much longer. Test 4 also had the most groups to complete the task. This shows that with behavioral realism, groups could get over that initial hump of where they were to discover the task and ultimately work together. This correlates with observations of the video and the self-reported values of Copresence and Psycho-behavioral Interaction.

As a user's identity is projected into a digital embodiment, whichever attributes that are expressing has the potential of resulting in a form of bias or stereotype. As discussed previously, a gender bias can affect one's performance of a task and race can affect one's perception of a situation. We bring social norms and bias into VR with us and take norms and bias along when we leave. In this study, I explored a way that could possibly eliminate certain bias, like gender and race, as way of having a positive influence on the environment. I did not test for this directly, but I feel that in creating a minimalistic form for a digital embodiment, neither race nor gender had any effect on the way people perceived themselves or each other in the environment. I questioned this by asking people to try and identify each other based off their actions. Few could correctly guess this, demonstrating that minimal attributes were carried over into the space. VR provides a blank slate for people to work together through minimal embodiments and create shared experiences.

In conclusion, I revisit the primary research question: How can minimal individual visual representation communicate social presence in a virtual reality environment? When visual representation is reduced to an abstracted form for digital embodiment, users are more apt to disclose information to each other and bring less bias into the environment with them, which helps them work better as a team to reach a group consensus. Having a way to interact acts upon our primal desire to be social and together with other individuals. The understanding of these four concepts: being together, willingness to disclose, collaboration, and reduced bias provides an ample lens for a digital embodiment in virtual reality that encourages social awareness and social behavior without becoming distracted with the representation.

FURTHER RESEARCH & EXPLORATION



The first step in moving forward with this research is filling out the initial retinal variable matrix and exploring the effects of social presence as I change scale, value, texture, hue, intensity, orientation and shape. In addition, I would like to bring in additional behavioral changes like speed. What happens if the user intends to move faster or slower, how does that affect other individuals' perceptions? As I start to complete this chart, I see my project transforming into a VR tool that helps researchers, designers and developers. I see designers and developers feeding back into the VR tool to expand our understanding of how we represent each other in VR environments.

This information will help them create their own applications that utilize what we learn about minimal form representation in VR. In the above chart, this is can be anything, so I left it open because as designers and developers explore this tool and distribute their own application, my initial VR tool can take on a whole life. To get this going, the VR tool would need to add additional dimensions: audio communication, haptic feedback, spatial representation, and textual representation. I did a preliminary test with audio communication with a group, using the same parameters as all my tests for this investigation, and participants' enjoyment seemed to raise, and well as overall

Fig 12: As this VR prototype is expanded, here depicts possible directions it could take and who it will benefit.

awareness of each other. From further testing, I see this as a way of achieving higher levels of social presence. In addition, I looked at vibration feedback for signaling aggressive behavior. I observed the vibration to introduce additional awareness of people and discourage aggressive behavior. Spatial and textual representation explorations could follow the same logic as this one, looking to see how abstracted environments and language representation affect a user's understanding of that representation. While I was unable to include spatial and textual representation in this project, I believe that they have additional influences on a user establishing social presence.

In addition to designers and developers having a tool to establish basic visual representation, this VR platform could provide a testing ground for researchers to explore other concepts, especially in behavioral science. Towards the end of my test, I spoke with Dr. Patrick Quinn, licensed psychologist and behavior analyst. He spoke of the importance of getting feedback from client observations, providing support for group therapy, and coaching managers on leadership and emotional intelligence. VR is a data-driven environment, much like any computer program. The program sends and receives data. This is how it knows what to do. From that, much like I included with test 4 and 5, the program could provide real-time feedback for observers viewing the client.

In my tests, I observed aggressive and assertive behavior, but in other environments my platform could track how often a user darts their eyes, how long someone stares at a given spot, etc.. Once the platform includes audio, it could track voices in real-time to give an analyst data about word usage. The platform is recordable for live and delayed viewing. In group therapy, Dr. Quinn stated that one of the issues is word usage— encouraging group members to not talk too much or to use language that would discourage positive group conversation. The VR platform could give personalized feedback to one individual. A warning could pop up in their headset, suggesting that they give someone else time to speak. If a member uses phrases that are known for creating tension in the group, they could receive a buzz. Maybe the moderator wants the group to know that this is bad behavior and the user could change color. This becomes a teachable moment the moderator could utilize.

In coaching managers on leadership and emotional intelligence, the VR platform could enable all participants to leave their former title behind to enter the environment. They would then have to work together and strategize the problem. Using different scenarios, one individual could sit out and direct other participants doing different tasks. That individual would have to learn how to give orders while not having their hands in the space directly. This becomes an interesting platform that works with people who are both co-spatially located and working together in different locations. Like group therapy and clinical observations, participants can get different feedback about their actions and behavior. In an environment that users can control and log, behavioral psychology stands to benefit from this platform.

Many fields are benefiting from virtual reality, currently, from architecture to gaming to education to socializing. As VR becomes more pervasive in the home and our culture, designers need to be asking how we are designing for it. Realism is not the definitive approach for immersing users in this medium. This investigation provides a foundation for further research into digital embodiments. To develop a methodology of translating what we know about social interactions to virtual reality that is not dependent on realistic human-like representation.

APPENDIX A

BERTIN'S RETINAL VARIABLES (CONT.)

Value

Value is the total amount perceived on a given object within a plane. Value is independent of the color hue; however, it still is part of the color of an object. There are limitations for users perceiving value. In situations of selection, more than 6 or 7 steps is difficult to read. When combined with size, smaller sizes also make value variations difficult (74).

Orientation

Orientation is the difference of the angle from one object to another within an area. The orientation variable has an infinite number of variations; however, like the other variables, there are diminishing returns on 5 or more orientation variations. The standard orientations are 0º, 30º, 45º, 60º and 90º. This variable combines well with shape and texture.

APPENDIX B

TEST VARIATION

1. **Multiplayer**
   From this point on in the test, I included multi-player. I added Photon Unity Networking, PUN, to the scenes and I had players join over a network. They would enter as different colored spheres. From observations players would start playing a game of hide-n-seek or other find/search games. At this point in the development I let users speak to each other during use. Common questions were "Where are you?" and "Are you the [color] ball?"

   At this point, there was still no task in the environment and I did not resolve the sliding issue. Users' movements were not tracked well in the space and their movements were discrete. Play would appear to be "laggy" to each other. If a player was disconnected they would come back as a different color sphere.

2. **Reticle addition**
   Google Cardboard SDK has a reticle object that it uses with the raycaster. It's the built-in process for user's gaze input. I added the reticle for the possibility of a gaze input. In addition, having the reticle present in the scene gives users something to focus on. This seemed to reduce motion sickness and nausea. This was a small update but was a way of preparing for possible future variations. Movement at this point had not been fixed.

3. **Use of walls (invisible)**
   Up until this point, if a user fell off the play area, they would fall forever. The only way to get back on was to restart the application. To remedy this, I added invisible boxes with box-colliders on them that acted as walls. I placed them around the play area. This prevented people from falling off.

4. **Better movement (less slide)**
   For the sake of usability, I temporarily fixed the sliding issue of users in the space. I increased the drag and angular drag of the spheres. To the best of my knowledge at this point, it was fixed. This was a minor variation.

5. **Plane space environment**
   At this point in my test, I moved away from the realistic forest environment. I created an area that was just a simple plane. This becomes my test area for trying out different inputs and mechanics until I landed on my experiment environment.

6. **Gaze-depicted input**
   The first thing I tested in my environment was different possible ways of visualizing gaze for a user. For this test, I turned off multiplayer to focus in the how gaze was visualized. I started with six general visualizations: one where the other sphere would start glowing, it released particles, it said "Hello" above itself, it only appeared when looking at it, it started playing a sound, and it was the only way to talk to each other. These six visualizations were basic starting points to explore how a user could know when another user was looking at them. In embodiments that have eyes or faces, this is done more naturally. When an embodiment does not have any of those "naturalized" features it begs the question of what is needed to deliver that behavior.

7. **2-D hub screen**
   As my scenes in Unity3d started to grow for my various tests, I needed a Hub to pick which scene to load. I started with a simple 2D hub with buttons on it for each scene I needed to add. I included short title of the scene that described what it was, like "Multiplayer – World" or "Gaze Test."

8. **Multi-player with gaze input**
I added multi-player back in and picked one of my visualizations from the gaze test. I used the particles. In this test, whenever a user stared at another user, the one doing the staring would start emitting white particles from their figure. The point, like before, was to show other users who were watching their movements. I also included a big red sphere. This was an inanimate object that allowed for interactivity between two users or by themselves.

I was unable to get the particle system to show up for people over the network at that time. I did not understand how network synchronization through messages over PUN worked. Because I was unable to get that system to work, I was unable to observe the effect on users and scrapped the idea for my test.

9. **Multi-player with box**
I created a new scene. I made the ground plane pink, gave the background a skybox for some color. I added a PUN box and a PUN plane to the environment. I kept the big red ball from the previous test. The box and plane came from a demo provided with the PUN tutorial. When a user clicked the plane, it was to instantiate a box. Users could run into box like the red ball to push it around the scene.

This is when I noticed there was some issues with pushing objects in the space. When a user pushed it, the camera would enter the space of the object and it would become temporarily invisible. It was also prone to going over the user. From a usability standpoint, it was awkward.

10. **Switch to newer GVR SDK**
Google came out with a newer SDK. They switched from being called Google Cardboard and rebranded as Google VR, GVR. At the point they announced their own phone, Google Pixel, and higher-end headset, Daydream. This SDK was out before I started my test but I was having build problems with the newer SDK before, so I decided not to switch until this point. The newer SDK allowed for 3D sound, a better Reticle pointer, cleaner shaders and the code was easier to work with and ran better. After the update, there were no problems with building for my iOS devices.

11. **Selecting/Moving/Stacking boxes**
To give users a task for when they enter the space, I began working on users selecting boxes. The issue was making the user know it was selectable. I used GVR's native reticle style of the dot becoming an enlarged circle to demonstrate this. From there, a user could click on the block and move it around the area. The issue at first was the ability to click on the box and move around the space was the same thing. For the time being, I turned off the ability to move to avoid the confusion. The other issue was getting the box to move around the user. I solved this by making the box a child over the user. Then the box could rotate around the user. Another issue was if the box went below the ground plane, it would fall out of playable space. I solved this issue by adding a script to the moveable box that would have it translate to its position if it went below a certain Y value. I added more boxes to the space and gave clickability to all of them. In search for a task to give my users, I started with seeing how it would be to stack boxes to make a shape.

12. **Instantiating boxes/smashing into boxes**
I fixed the issue with the PUN plane that allowed users to create boxes. From there I could create as many boxes as I needed to create a basic shape. My initial idea was to ask users to create a pyramid together. After some user testing this was too difficult. Users also said that it was more fun to instantiate a lot of boxes and then crash into them, rather than build a pyramid with them. Moving away from this idea helped me understand how to create objects that are linked over the network.

13. **User became a box**
This variation and the one following happened almost at the same time. I decided, given that it was a mechanic change and a user embodiment change, to keep them separate. In this variation, I changed the users to boxes. This was because of the cultural perception that boxes are workmanlike, and it is easier to see when a user rotates their head.

The initial problem with the box was when I linked the boxes rotation to the user's head movement, the box skidded across the plane. This was because the box had a collider on it and so did the plane. If the box sat level on the plane when it moved, to reflect a user looking down, the lower edge of the box would try and go past the ground plane. This forced the box to move unnaturally across the plane. For the time being, I turned off this feature.

14. **Look and do puzzle – Big**
After the building blocks was deemed too difficult, I looked at another task-oriented environment. I created an environment where the users would go up a ramp to view a configuration of boxes on one

side of the wall and then try and move the boxes on their side to the same configuration. The idea for this environment was to give users the ability to discover and complete the task if they wanted. Seeing other people completing the task might encourage them to participate. I added the wall and ramp to entice people to discover the task but also to encourage movement around the space.

The issue that I ran into this environment was going up the ramp was too difficult. At this point, I still had the full head tracking turned on for the user cube and it made it difficult going up ramps. Even after I turned off the head tracking, it wasn't consistently easy, so I considered an alternative.

15. **Look and do puzzle - Small**
Since the previous environment was too difficult to move around and discover the puzzle to, I created a ramp-less environment with walls separating the user from the answer to the puzzle. Users would start in the environment with seven boxes lined up near a gridded floor and near a slit in the wall that they could move through. Once they moved through, they would see a large-scale replica of the room they just came from. Users could then travel back through the opening in the hole to push the boxes to the correct squares. After all the boxes were moved into the correct spot, a message saying "COMPLETED!" appeared on the wall.

16. **Timer**
A small update but to add more of a game mechanic to the space, I placed a 5-minute on the wall where the answer key was located. The timer started when the first user went through the split in the wall to look at the other side. It was a global timer that affected everyone. I included the timer to give the sense of urgency to completing the task. If all the boxes were not in the correct spot at the end of the five minutes, all the boxes were deleted and a message saying "FAILED" was displayed on the wall. Like the previous version, if all the boxes were in the correct spot, the message said "COMPLETED!"

17. **Deleted the "look" side - added lights**
After some testing, I realized that the timer and going from one side of the wall to the other was not conducive to the environment. To make the objective simpler, I added green lights over the appropriate squares on the grid. To give users feedback on their movements, the boxes turned green when on the correct square. In the previous tests, there was one smaller cube that was different than the rest. That cube had a specific square to enter while the rest could be in any square. This still held true for this test.

At this point, I began preliminary testing of my protocol for my experiment. All variations after this point were either fixes as results to bugs or testing out for possible experiments.

The next section details conditions of the experiments.

18. **Changed objects to spheres**
Both the users and the objects to push in the environment were cubes. Users commented that the cubes were too difficult to move and detracted from the environment. For ease of pushing objects in the space, I switched the objects to spheres. This created a visual distinction between users and objects. The spheres remained the same color as before, light blue with a light texture to help recognize that it is rolling.

19. **Added a mirror**
Since my initial tests, I had the stereoscopic camera that is a user's input into the VR environment, situated two units above the user's cube. The idea was for user to be able to look down and still see themselves. In preliminary tests, the idea that the user was the cube was not always conveyed. To help with this and ultimately establish self-presence for the user, I added a mirror into the space. The mirror ran ¼ of the wall near the starting area for every user. I will discuss the results from the mirror in the findings section.

20. **Better push movement**
One of the main usability flaws in the environment was the push mechanic. It was hard for users to push because the sphere would rubber-band from its spot. This was improved when I learned that the PUN utility had its own transform script that sent better network messages to update the movement for all other users.

21. **Spectator View**
In preparation for running tests, I needed a way to have a consistent view of the playing area from test to test. I added a spectator view that I put onto an iPad. If the program noticed that the device being used was any generation of an iPad, it did not create a playable character; instead, it turned on a monoscopic camera that pointed down from overhead of the playing area. Although it was in perspective, it was a top-down view. This allowed me to plug the iPad into the computer and record the iPad screen directly. In initial tests, I was recording a portion of my computer screen. This made each video slightly different.

22. **Left-right movement tracked and translated**
As I have previously stated, I had difficulty translating user's head movement to reflect in the user's cube. This was because I was trying to track X, Y, and Z head rotation. The X and Z rotation caused the cube to collide with the ground plane and move across the floor on its own. This created an uncomfortable sensation for the user. In preparation for the first experiment, I turned on the Y rotation, while keeping the X and Z rotation off. This projected the user's left right head movements onto the cube. This helped other users understand their movements.

23. **Buttons - get big or small**
Looking back at my matrix of the various variables and possible ways of representing it, one was scale. This tests gave users the ability to look up and click either a "+" or "-" to change their scale. One click of the "+" increased the user's scale from 1 to 4. A click to the "-" would bring it back to 1. Another click would bring it down ¼ size.

One issue that arose in this test was when users got down to the smaller size. If a user pushed themselves into the center of the mirror, they would fall through the floor and off the map. The other way to get them back is by restarting the application. I was unable to resolve this issue.

24. **Buttons - get brighter or darker**
Similar to the previous variation, this would change the color value. It would iterate between a light version of the user's color, the normal state and the dark version of the color. This test was never officially conducted with users but it became a way to explore the effect of color.

25. **Proximity depicts Hue variation**
In this test, I explored the possible effect of user's passive behavior, proximity, on the color of themselves and others. At any given moment, the user's cube checked who the closest user was to him/her. Based off the distance between the two users, their color would change. If a third user was closer, the other user would change once the first user was closer than the third user. Given this was a passive behavior and did not allow users to project their own selves into the space, I tabled this test.

26. **Full head tracking (up, down, left right)**
One of the main issues I had with head tracking before was the cube colliding with the floor. In this test, I lifted the cube off the floor three units, and let it share space with the camera. This prevented the ground and cube from colliding and full head tracking was made possible. In this test, a user could not look down and see themselves. This made the mirror was more important than previous tests. Observations and results from my findings will be in the following section.

27. **VR hub screen**
Until this point, my loading screen into the application was a 2D screen with buttons. To extend the VR experience from the app, into the test selection scene, I added a room that allowed users to pick which test to load. While I do not let users pick the test during my experiments, I built this environment to provide room for future exploration.

28. **Better push movement**
After further research and testing into the PUN utility, I found why the push mechanic felt awkward for users. This was because PUN makes all objects in the space have owners. In the case of my environment, the first person into the test, or master, was the owner of all the spheres. This meant that it was easy for them to push but no one else. I discovered that I could transfer the ownership from person to person. After implementing this, the push mechanic became more fluid and less awkward.

29. **Color changes**
In the third month of test variations, PUN had an update that corrected some back-end issues that I was having with the application. Upon updating the utility, it removed my pre-set player's colors. In resetting them, I chose colors that matched the color scheme of the space. Because of the update, if a user left the room, when they returned they came back as the same color instead of a different color. I was glad Photon fixed that issue.

30. **Behavior Chart**
From my observations, I noticed the same general behavior: passive, assertive and aggressive. To help record the instances of these behaviors, I added a chart that only appeared on the spectator view. The chart was be the sum of the instances of all users during any given session. This appeared in the lower right-hand corner of that screen.

31. **Front face - lighter color**
For this test, to visualize what way a user is facing to everyone else in the space, the front face of the user was a lighter color than the rest. This was done dynamically on users joining the testing room. The value was brightened by 20%. Observations and results from my findings will be in the following section.

32. Avatars are spheres

For my last variation, I switched the users back to spheres. For this test, I added a texture that still gave users an idea of everyone's "font face." To keep with the previous tests, all users floated three units off the ground plane. I wanted to keep that constant between the last three tests. I also ran into the issue that the sphere would roll on the ground, separate from the user's head movement. Observations and results from my findings will be in the following section.

APPENDIX C

PARTICIPANT SURVEY AND NETWORKED MINDS THEORY QUESTIONNAIRE

Sex
Age
Can you identify what you were in the space?
What were you?
What helped you identify yourself?
Were others in the space with you?
What were they?
Were the others in the space

Co-presence

Perception of Self	**Perception of Others**
I often felt as if the other individual and I were in the same room together.	I think the other individual often felt as if we were in the same room together.
I was often aware of others in the room.	Others were often aware of me in the room.
I hardly noticed others in the room.	The other individual didn't notice me in the room.
I often felt as if we were in different places rather than together in the same room.	I think the other individual often felt as if we were in different places rather than together in the same room.

Psycho-behavioral Accessibility

Attentional Awareness	
Perception of Self	**Perception of Others**
I paid close attention to the other individual.	The other individual paid close attention to me.
I was easily distracted from the other individual when other things were going on.	The other individual was easily distract from me when other things were going on.
I tended to ignore the other individual.	The other individual tended to ignore me.

Perceived Comprehension	
Perception of Self	**Perception of Others**
I was able to communicate my intentions clearly to the other individual.	The other individual was able to communicate their intentions clearly to me.
My thoughts were clear to the other individual.	The other individual's thoughts were clear to me.
I was able to understand what the other individual meant.	The other individual was able to understand what I meant.

Emotional Contagion	
Perception of Self	**Perception of Others**
My actions were often dependent on the other's actions.	The other individual's actions were dependent on my actions.
My behavior was in direct response to the other individual's behavior.	The behavior of the other individual was often in direct response to my behavior.
What I did affected what the other individual did.	What the other individual did affected what I did.

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